2020-02

Faecal Sludge Management Situational Assessment: A Case of Kombolcha Town, Amhara Region, Ethiopia

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BAHIR DAR INSTITUTE OF TECHNOLOGY

SCHOOL OF RESEARCH AND POSTGRADUATE STUDIES

FACULITY OF CIVIL AND WATER RESOURCES ENGINEERING

WATER SUPPLY AND SANITARY ENGINEERING PROGRAM

FAECAL SLUDGE MANAGEMENT SITUATIONAL ASSESSMENT: A CASE OF KOMBOLCHA TOWN, AMHARA REGION, ETHIOPIA

MASTER'S THESIS

By

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Bahir Dar, Ethiopia

February 17, 2020

FAECAL SLUDGE MANAGEMENT SITUATIONAL ASSESSMENT: A CASE OF KOMBOLCHA TOWN, AMHARA REGION, ETHIOPIA

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A thesis submitted to the school of Research and Postgraduate Studies of Bahir Dar Institute of Technology in partial fulfillment of the requirements for the degree of Master of Science in Water supply and sanitary engineering in the faculty of civil and water resources engineering.

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February 17, 2020

DECLARATION

I, the undersigned, declare that the thesis comprises my own work. In compliance with internationally accepted practices, I have acknowledged and refereed all materials used in this work. I understand that non-adherence to the principles of academic honesty and integrity, misrepresentation/ fabrication of any idea/data/fact/source will constitute sufficient ground for disciplinary action by the University and can also evoke penal action from the sources which have not been properly cited or acknowledged.

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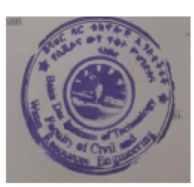

ACKNOWLEDGMENTS

I am very grateful to the most merciful and almighty Allah for all the things done for me in my entire life and helping me to see this through to the end.

I would like to express my deepest thanks to my advisor Dr. Atekelt Abebe and co-advisor Mr. Eshetu Assefa for their consistent precious advice and follow up from start to the completion of this thesis.

A special thanks and recognition go to the Bahr Dar Institute of Technology-Bahr Dar University for the opportunity to pursue this master's program as I seek to learn more in the mission to help my country in clean water supply and improved sanitation provision arena.

Special thanks also go to Mr. Tilk Tena who helped me through initiating to do my research in this thesis title and for his continuous advice and support. I also want to extend my heartfelt appreciation to Dr. Tamru Tesseme for his desire to comment and advise on this thesis. I also would like to express my deepest thanks to my progress examiners Mr. Lakachew Y. and Dr. Dagnachew A. for their valuable comments.

I also extend my gratitude to the Kombolcha Town administration divisional officials, Kombolcha water supply and sewerage authority officials, Kombolcha town health department, and various municipality's stakeholders who assisted me through interviews. I also thank the service providers and community members who agreed to share their perspectives and insights with me and for making discussions.

Lastly, I would like to address my deepest thanks to my families for their moral support and my special persons Yimer Endris, Elyas Abebe, Tewodros Dessale and his wife Metafet., Anwar Mohammed, Amanuel Biset, Alemayehu Ali, Tesfaye Wodaje and my wife Habiba Misbah who had major involvement and encouragement for the accomplishment of this research.

ABSTRACT

Nowadays, fecal sludge management (FSM) is a global concern, particularly in low-income countries which predominantly rely on on-site sanitation technologies. That's why, in poor and growing urban areas of those low-income countries like Ethiopia, fecal sludge management represents a growing challenge; generating significant negative public health and environmental risks. Thus, this study was carried out to investigate the current fecal sludge management situations in Kombolcha town. To address the research objectives, household surveys, field observation, focus group discussions, key informant interviews, and relevant document reviews were used. For credible preliminary data analysis, SPSS and Micro Soft Excel were used and followed by Shit Flow Diagram (SFD) analysis. The SFD methodology was primarily used to highlight the extent of problems or gaps in an existing fecal sludge management situation. Following SFD results, public health hazards and community perception assessment has been conducted for the comprehensiveness of the study. The study identified 75.7% of households rely on shared toilets with two and above households. Five main toilet technologies of households were also identified in Kombolcha town: Cistern flush toilets - 2.1%, Pour/manual flush toilets - 19.8%, Ventilated Improved Pit latrine (VIP) – 11.1%, Pit latrine with and without slab (56.4% and 10.7% respectively). However, only 37% of households were experienced in a pit/tank filling up and emptied their facility to reuse again. The final SFD result presented 56% of fecal sludge safely managed and 44% unsafely managed. While 76.5% of fecal sludge contained and 16.5% not contained on-site. Issues arising out of health risk exposure valuation identified pit/tank overflow occurrences, poor children feces management, open defecation practices, and indiscriminate fecal sludge or black water discharges as a primary source of health hazards. Furthermore, the study identified the inhabitant‘s remark; the need for subsidies, additional construction and/or rehabilitation of existing public and communal toilets, enforcement of sanitation bye-laws as well as proper supervision, inspection, and monitoring of sanitation facilities and services so as to improve the present fecal sludge management practices.

Keywords: Faecal sludge management, Shit flow diagram, and Sanitation service chain.

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LIST OF ABBREVIATIONS

CSDA	City Service Delivery Assessment
CLUES	Community Lead Urban Environmental Sanitation
FGD	Focus Group Discussion
FMoH	Federal Ministry of Health
FS	Faecal Sludge
FSM	Faecal Sludge Management
FSTP	Faecal Sludge Treatment Plant
HCES	Household Centered Environmental Sanitation
HH	Household
ISO	International Organization for Standardization
IWA	International Water Association
JMP	Joint Monitoring Program
KII	Key Informant Interview
KTSBD	Kombolcha Town Sanitation and Beautification
KTWSSA	Kombolcha Town Water Supply and Sewerage Authority
LMICs	Low and Middle-Income Countries
MDG	Millennium Development Goal
NGOs	Non-Governmental Organization
SSA	Sub-Saharan Africa
SDG	Sustainable Development Goal
SFD	Shit Flow Diagram
SFD-PI	Shit Flow Diagram Promotion Initiative
SPSS	Statistical Package for Social Science
SSC	Sanitation Service Chain
SuSaNa	Sustainable Sanitation Alliance
PTs	Public Toilets
UNICEF	United Nations Children's Fund
VIP	Ventilated Improved Pit
WASH	Water Supply, Sanitation, and Hygiene

WHO	World Health Organization
WSP	Water Supply and Sanitation

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1. INTRODUCTION

1.1 Background

Safe sanitation is indispensable for human health through preventing infectious diseases, promoting, and sustaining physical, mental as well as social well-being. However, sanitation is also a building block of development (WHO, 2018). The sanitation requirements of 2.7 billion people across the world are met by on-site sanitation technology. Likewise, around one billion onsite sanitation technologies serve worldwide in urban areas (Strande & Brdjanovic, 2014). Even though most of the on-site technologies in the middle and low-income countries meet the needs of users in urban areas, the typical on-site management system is the accumulation of feces in heavy slime (Strande, 2014).

Likewise, billions of people live without access to even the most basic sanitation services. Many people worldwide practice open defecation and many more do not have services that prevent fecal waste from contaminating the environment. 2.3 billion people who still lacked a basic sanitation service either practice open defecation (892 million) or use unimproved facilities (856 million). The remaining 600 million use limited sanitation facilities that are shared with other households (WHO and UNICEF, 2017).

Fecal sludge management is today's global priority, as many developing countries move to increase their sanitation coverage. Without proper management, fecal sludge is often allowed to accumulate in poorly designed holes, drained into stormwater and into open water, or dumped into waterways, waste, and non-landfills, resulting in global deep impacts (Chowdhary and Kone, 2012). In poor and rapidly expanding cities fecal sludge management (FSM) signifies a growing challenge; generating significant negative public health and environmental risk (Peal et al., 2015). Consequently, billions of people are exposed to harmful pathogens such as diarrhea, soil-transmitted helminth infections, schistosomiasis, trachoma, vector-borne diseases such as West Nile Virus, lymphatic filariasis and Japanese Encephalitis (WHO, 2018).

Ethiopia faces various sanitation problems related to a low level of priority for sanitation, poverty, unavailability of equipped skilled human resources, unclear institutional framework, and responsibilities. As a result, only 4% of rural and 16% of urban households use improved toilet accommodations. About 56% of rural households rely on unimproved toilet facilities and more than 35% of toilet accommodations are shared in urban households, whereas only 2% of rural households share their toilet facilities with other households (CSA and ICF, 2017). One in three Ethiopian households have no toilet facility; defecate to bush/fields (39% in rural areas and 7% in urban areas) (CSA and ICF, 2017). Furthermore, according to the WHO (2014) estimates, diarrhea contributes to more than one in every ten child deaths in Ethiopia. The total population growth rate of Ethiopia is also 2.5% a year, with urban centers growing at a rate of 5.1% (Haddis et al., 2013). This situation makes fecal sludge management difficult, especially in poor urban areas.

To overcome this problem, there is a need for research on the links between fecal sludge and health, on the operation of the sanitation service chain and optimal methods for implementation (WHO, 2018). However, no field research and evaluation conducted on the entire fecal sludge management systems up till now and non-existence of published documentation of comprehensive assessments comprising containment, emptying, transport or convey storage or treatment, and reuse or disposal, based on actual practices for most of Ethiopian cities and towns; particularly Kombolcha town except the WHO and UNICEF country-level estimations.

Researches on fecal sludge management service play a crucial role to save lives and to safeguard community health. Thus, this research was conducted for fecal sludge management valuation and identification of management gaps as well as isolating building blocks for action; to contribute some ideas in improved sanitation provision arena so as to bring priority and monitor sanitation through fecal sludge management.

1.2 Statement of Problems

Improved sanitation provision is a challenging task in developing countries, especially in sub-Saharan countries. Among those low-income sub-Saharan countries, Ethiopia struggles with poor fecal sludge management problems. The urban sanitation coverage of Ethiopia indicates, 49% of the community depend on basic (private toilet facility) and shared toilet facilities. Whereas, the remaining (51%) community depends on unimproved traditional pit latrine (44%) and open defecation (7%) that exposed to excreta and results in public health risk exposure (WHO and UNICEF, 2017). Particularly those problems are the major features of Kombolcha town.

Presently, in Kombolcha town, following the expansion of numerous industries, the number of populations is extremely increasing. Likewise, the fecal sludge management challenge is also increasing day in day out. Fecal sludge management is also not adequately addressing the sanitation provision gaps for safe containment, collection and transportation, treatment, and disposal of fecal waste. As the result, overflow/leakage from public, private and communal toilets, inadequate number of public and communal toilets, illegal pit/septic tank outlet connections from condominium and private houses to drainage canals and water bodies pose a health threat. In addition, unsanitary circumstances, such as open defecation practice together with related problems lead to extremely serious community health and environmental problems; as a witness 5040 under age five children exposed to diarrhea according to the Kombolcha health center report in the year 2017/18.

Accordingly, an assessment of existing fecal sludge management services and significant factors that influence its performance are crucial to formulate management measures so as to improve the current service. So, this research was conducted to assess the existing FSM situations and to provide baseline data for future intervention option planning prospects.

1.3 Objectives of the Study

1.3.1 General Objective

The main objective of this research is to investigate the current fecal sludge management situations for Kombolcha town.

1.3.2 Specific Objectives

Specific objectives that are to be achieved through this study are as follows:

- To identify existing onsite sanitation technologies and assess their way of management arrangements in the town.
- To develop SFD for the current status of fecal sludge management situation and show problems/gaps along each stage of the sanitation service chain.
- To identify public health hazards or risk exposures associated with poor fecal sludge management practices.
- To recognize the community perception of current fecal sludge management practices.

1.4 Research Questions

Based on the specific objectives enumerated above, the study was achieved by answering the following questions:

1. What various household, communal and public latrine technologies exist in town and what is their respective management trend?
2. Where is the wastewater and fecal sludge primary destination in the town and what proportions are safely managed?
3. What problems or gaps encountered because of poor fecal sludge management along the sanitation service chain?
4. What public health and environmental hazards or risk exposures occurred related to poor fecal sludge management gaps or problems?
5. What are the community perceptions and attitudes towards the current fecal sludge management provisions?

1.5 Scope of the Study

The scope of the study is limited in space and theme. The study was limited in scope to Kombolcha town urban kebeles and limited in a theme to residential premises or settings. To meet the objective, the study covered fecal sludge management service provision examination from containment up to disposal sites throughout the service chain with the application of diagnostic tool (SFD) so as to identify sanitation service provision gaps and stages of sanitation service chain under higher prioritization. Accordingly, the study embraced the identification of latrine technologies and their management trends, excreta flow mapping, and assessment of community perceptions of the current FSM situation as well as health hazards or public health risk exposure valuation.

1.6 Significance of the Study

The study aims to assess the current fecal sludge management situations and map excreta flows along the sanitation service chain so as to identify gaps at every stage of the chain. Besides, it can be further cooperative in identifying the degree of health hazards or threats, public perception and potential service demands. Generally, the study provides baseline data concerning FSM for future intervention option planning.

Especially, development banks, NGOs and private investors will become interested to invest for sensitive specific problems along the sanitation service chain. In addition, decision-makers and concerned bodies will give more emphasis and solutions for identified problems rather than the whole technical aspect problems due to limited resources. They also bring priority and monitoring sanitation by creating an enabling environment.

Mostly, the research output is supportive for national, regional, municipal authorities and other stakeholders to inspire and empower to take actions for identified gaps at their level; in order to facilitate sustainable and reliable improved FSM provisions.

Now a day, there has been an increased focus on sanitation improvements; thus, this study serves as an initial standpoint for further technical intervention options assessment and technical design for Kombolcha town. This study will also serve as a reference for those working in SFD related fecal sludge management investigations in other towns.

1.7 Limitations of the Study

- Difficulties in data collection and key informant interviews (KII) with different stakeholders due to their poor data management system and unclear responsibilities. This situation resulted in slowing down the in-depth analysis.
- Limitations on financial resources have also limited the work of the present study to conduct (CSDA) city service delivery assessment, health risk and intervention option assessment following the developed SFD for further investigation.
- Lack of sufficient existing data related to the present study and difficulty to find similar previous studies related to FSM in Kombolcha town.
- Unfamiliarity with Faecal sludge management diagnostic tool i.e. (SFD) resulted in a delay of data collection and analysis period to come up with its methodology.
- The number of focus group discussions made was relatively small, compared to what would be required for the size of the town due to the stakeholder’s other own priority that makes them to not take time and discuss.
- However, even with all these difficulties and limitations, all efforts were made to conduct this research in a systematic manner, which were all supported by the actual field observation and transect walk, key informant interviews, focus group discussions, and household survey.

2. LITERATURE REVIEW

This chapter presented kinds of literature from various forms of sources. The compiled literature in this chapter explores the predominant sanitation system from a global outlook and narrow it down to a country level. In addition, Sustainable Development Goals (SDGs) for sanitation has been reviewed to have insight about SDG goals forwarded. i.e. "Ensure availability and sustainable management of sanitation for all". Furthermore, this literature review addressed fecal sludge management which is nowadays a worldwide concern especially in medium and low-income countries like Ethiopia. Correspondingly, the chapter explores FSM challenges and developed tools aiming to overcome the challenge through rapid assessment. Specifically, this literature review focuses on an overview of SFD and its potential in controlling urban sanitation challenges. Likewise, poor FSM related health hazards and public perception mapping are parts of the literature review in this chapter.

2.1. Sanitation Overview

2.1.1 Importance of sanitation

Sanitation is defined by the World Health Organization (WHO) as the "provision of facilities and services for the safe disposal of human urine and feces" (WHO, 2017a). Safe sanitation is essential for health, from preventing infection to improving and maintaining mental and social well-being. The lack of safe sanitation systems leads to infection and disease, including (WHO, 2018) diarrhea. Major public health concern; a leading cause of disease and death for children under five years in low- and middle- income countries (Troeger et al., 2017) are:

- ☞ Neglected tropical diseases such as soil-transmitted helminth infections, schistosomiasis and trachoma that cause a significant burden globally (WHO, 2017a); and
- ☞ Vector-borne diseases such as West Nile Virus, lymphatic filariasis and Japanese Encephalitis (Van den Berg et al., 2013) through poor sanitation facilitating the proliferation of Culex mosquitos.

Unsanitary conditions have been linked with preventable diseases which affect almost one-quarter of children under-five globally (UNICEF, WHO, & World Bank Group, 2018) through several mechanisms including frequent diarrhea, helminth infections (Ziegelbauer et al., 2012) and environmental enteric dysfunction (Crane et al., 2015).

It is estimated that some 280,000 persons die yearly due to diarrhea-related diseases which could be prevented with access to better sanitation provisions (WHO and UNICEF, 2017). Adequate sanitation can produce an economic benefit that $ 1 invested in sanitation can produce a return of up to US$ 9 (through indirect channels such as savings on money spent on health and better productivity (Singh et al, 2017). Globally, the impact of interventions can be as much as US$ 260 billion (Blackett et al., 2016); hence the need to address the issue of sanitation.

2.1.2 Sustainable development goals (SDGs) for sanitation

The Sustainable Development Goals (SDGs) of 2015 are aimed at solving the unfinished work of the MDGs and are aimed at continuing the new development agenda while addressing the gaps identified during the implementation of the MDGs (Kumar et al., 2016). In developing the SDGs, a specific goal was formulated, that is, SDG 6, to bridge the gap in the provision of basic services in the field of water supply and sanitation. GOAL 6 aims to “ensure the accessibility and sustainable management of water and sanitation for all” by 2030. In particular, objective 6.2 aims to ensure adequate sanitation and hygiene for all and end open defecation, with particular attention to the needs of women and girls and those in vulnerable situations (WHO and UNICEF, 2017).

Any achievements that are unnecessary to the needs of the community, and such a lack of sanitation, have raised the possible budget gap (Kumar et al., 2016). The SDG targets apply to all countries and the JMP proposes to use a ‘service ladder’ approach to benchmark and track progress across countries at different stages of development. Emerging JMP ladders build on existing datasets and introduce new indicators that reflect the ambition of the new SDG targets (WHO and UNICEF, 2017). There are three categories of JMP delimited sanitation facilities: limited, basic and safely managed services (Figure 1). The population using improved facilities that are shared with other households will now be called limited rather than shared. Improved facilities that are not shared count as either basic or safely managed services, depending on how excreta are managed (Figure 1). The JMP will also continue to monitor the population practicing open defecation, which is an explicit focus of SDG target 6.2. (WHO and UNICEF, 2017)

Safely managed	Use of improved facilities which are not shared with other households and where excreta are safely disposed in situ or transported and treated offsite
Basic	Use of improved facilities which are not shared with other households
Limited	Use of improved facilities shared between two or more households
Unimproved	Use of pit latrines without a slab or platform, hanging latrines or bucket latrines
Open defecation	Disposal of human faeces in fields, forests, bushes, open bodies of water, beaches and other open spaces or with solid

Figure 1: The components of the SDG sanitation ladder (WHO and UNICEF, 2017)

2.1.3 Status of sanitation worldwide and in Sub-Sahara Africa

Improved sanitation refers to "systems that hygienically separate human excreta from human contact and includes: flush toilets, connection to a piped sewer system, connection to a septic system, flush/pour-flush to a pit latrine, ventilated improved pit latrines (VIP), and composting toilets." (Strande et al., 2014). An assessment of progress made against the MDG targets by the Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP) in 2015 revealed that globally progress had been made in increasing the access to improved sanitation from 54% in 1990 to 68% by 2015 (WHO/UNICEF, 2015). Despite this improved coverage, 2.4 billion people still do not have access to basic sanitation services. In Sub-Sahara Africa (SSA), it is estimated that 17% of the population (or 695 million people) still lack basic facilities (WHO/UNICEF, 2015).

2.1.4 Sanitation coverage in Ethiopia

Ethiopia was praised in the global WASH JMP report of 2015 as having made the most remarkable progress in terms of water, sanitation and hygiene coverage. From just 8% sanitation coverage in 1990, it had increased to 71% in 2015, 25 years later. "Open defecation was practiced by 44.3 million Ethiopians in 1990 and 28.3 million in 2015 (from 92% in 1990 to 29% in 2015) an average reduction of over 4 percentage points per year over 25 years" (WHO/UNICEF, 2015). However, this result is slight when compared with what is needed to provide safe sanitation service for the community.

Urban Sanitation coverage of Ethiopia in the year 2015 was 19% out of the total population of 98,942,000. Out of the total number of urban populations, 27% used improved sanitation and the remaining 73% implies unimproved sanitation facility coverage (6% faced to open defecation, 40% shared toilets, (WHO/UNICEF, 2015) in addition 27% remains pit latrine without slab). According to JMP (WHO and UNICEF, 2017) urban sanitation coverage in Ethiopia for basic, limited (shared), unimproved sanitation facilities and open defecation recorded as 18%, 30%, 44%, and 7% respectively. In addition, the proportion of the population using improved sanitation facilities (excluding shared) with safe management remains only 4% in rural areas (WHO and UNICEF, 2017).

2.2. Sanitation Systems

Sanitation is defined as access to and use of facilities and services for the safe disposal of human urine and feces; whereas safe sanitation system is a system designed and used to separate human excreta from human contact at all steps of the sanitation service chain from toilet capture and containment through emptying, transport, treatment (in-situ or offsite) and final disposal or end-use (WHO, 2018). It links technologies that facilitate the movement of fecal matter from the point of generation to the point of disposal (Tilley et al., 2014).

Sanitation systems can be broadly categorized into two classes as either the conventional system or on-site sanitation systems (Virgolim, 2017). The conventional system typically consists of sewer networks that drain to a centralized treatment plant and are often adopted to areas with a high population density in addition to access to high water volumes since it requires water to operate efficiently (Reymond et al., 2016). On the other hand, the on-site system is localized to household level as wet systems e.g. flush toilet and septic tank or dry systems e.g. basic latrines (Reymond et al., 2016).

2.2.1 On-site sanitation

On-site sanitation refers to a system that allows for the management of fecal matter near the point of generation, i.e. its collection, treatment, and disposal or reuse is within the vicinity of its production (ISO, 2016). Interestingly, this was the dominant method of sanitation (less the treatment component) before the advent of sewer networks and is now popularly known for its use in rural areas. Though popular in rural areas, currently on-site sanitation is accounting for between 65% to 100% urban sanitation in SSA (Strande et al., 2014). Due to the challenges posed by conventional sanitation systems in urban settings, attention has returned to on-site systems as they tend to be more applicable in particular contexts (considering factors such as difficult terrains, complicated construction, high costs, inadequate aptitude of management teams, intermittent water supply, and sparsely populated areas) (Starkl et al., 2015; Strande et al., 2014).

On-site sanitation systems have been acknowledged and recognized by the International Water Association (IWA) to come in a variety of forms all with the ultimate goal of providing sustainable sanitation solutions (IWA, 2016). In all, they have similar components which include the front end (or user interface), excreta containment, emptying, collection or transport and, backend (processes which follow collection and transport). Examples of such systems are pit latrines, cesspits, and septic tanks, dry toilets, and non-reticulated toilet blocks (Tilley et al., 2014; Strande et al., 2014). The inputs to these systems are normally composed of fecal sludge (FS) which comprises human urine and feces and in some cases greywater resulting from hand-washing. These systems result in the accumulation of FS at or near the point of origin. Additionally, the characteristics of the FS will differ with varying concentrations, consistencies, and quantities depending on the types of technologies (Strande et al., 2014).

2.2.2 Conventional sewer systems

Conventional sewer systems comprise a reticulated or piped collection system also referred to as a sewerage system, which collects and conveys wastewater of domestic, industrial or commercial origins away from the source to an endpoint for treatment and disposal; wastewater treatment plant (WWTP) (Reymond et al., 2016). This system ideally strives to ensure wastewater is collected, treated and the effluent disposed of appropriately with minimal exposure to the population. The system is designed to operate on a large scale i.e.

it comprises a network of users, for example, city-wide thus the WWTP becomes a central collection point for the wastewater. As a result, the system is also be referred to as a centralized wastewater system (Virgolim, 2017; Reymond et al., 2016).

The conventional sanitation system comes in a variety of forms depending on the context of use. It can be strictly sanitary or combined (conveying both wastewater and stormwater) (Price & Vojinovic, 2011). In terms of operation, these systems are heavily dependent on the availability of water which is used as the medium of transportation of the waste matter. In terms of investment and operation costs, the conveyance part of this system can contribute up to 90% of the total costs of the system. This is due to their strict demands on diameters (to prevent blockage) and slopes (to prevent settling of solids) which may require extra excavation. Based on parameters such as terrain, use, and budgets, adaptations of the reticulation network include the simplified system or settled sewage (small bore) and the vacuum system (Price & Vojinovic, 2011). Different treatment technologies are utilized at treatment plants to treat waste and these can be physical (mechanical e.g. screening, settling processes) to remove large and suspended objects or biological (microbial e.g. activated sludge) for the breakdown of soluble matter (Price & Vojinovic, 2011).

2.3. Fecal Sludge Management (FSM)

Fecal sludge: FS is a slurry or semisolid that is raw or partially digested and comes from the collection, storage or treatment of a mixture of excreta and black water (Singh et al., 2017). Fecal sludge comprises all liquid and semi-liquid contents of pits and vaults accumulating in on-site sanitation installation, namely un-sewered public and private latrines or toilets, aqua privies and septic tanks (Strande et al., 2014). The solid part that has been partially digested and settled at the bottom of the onsite sanitation systems is known as fecal sludge (Koottatep, 2014).

Fecal Sludge Management (FSM): It is an integrated approach to management, provision of technology and planning of sanitation services while providing a framework to guide projects from conception to operation (Strande et al., 2014). FSM includes the storage, collection, transport, treatment, and safe end use or disposal of FS, that means all five components of the sanitation value chain (Singh et al., 2017). It is a rapidly growing discipline that has been borne out of the need to address the problems of poorly managed fecal sludge. Strides have been made in the development and acknowledgment of FSM by stakeholders as seen by its adoption and use (Strande et al., 2014).

Planning helps to define suitable long-term strategies while stakeholder engagement and involvement deepens the understanding of needs and constraints while building longevity into projects. The management component ensures the longevity of technologies that are used or proposed, taking into cognizance issues of institutional and technical capacity; legal frameworks; and measures that allow for cost recovery. Besides the provision of improved sanitation, the FSM approach also presents an opportunity to harness and recover resources from FS. To adequately harness FS as a resource, some factors have to be considered and properly addressed, i.e.:

- Management and oversight of the facilities so that FS is treated adequately for reuse;
- Availability of enabling regulations;
- Clearly defined organizational roles; and
- Community awareness campaigns on reuse (WHO and UNICEF, 2017).

2.3.1 Faecal sludge management challenges

FSM deals with on-site sanitation systems and appropriate FSM which having a significant impact on human and environmental health. Till now FSM coverage is low and problematic, causing environmental and public health threats (Tilley et al., 2014).

Particularly in low-income and rapidly expanding cities this fecal sludge represents a growing challenge, generating significant negative public health and environmental risks. Without proper management, fecal sludge is often allowed to accumulate in poorly designed pits, or is discharged into storm drains and open water, or is dumped into waterways, wasteland and unsanitary landfill sites. Only a small percentage of fecal sludge is managed and treated appropriately (Peal et al., 2015).

The entire service chain needs adequate management to ensure the protection of public and environmental health. However, in the majority of low-income countries, adequate FSM is not in place. Although there are no global statistics on FSM like the MDGs, some recent studies reflect the serious situation and current fecal sludge crisis. The World Bank Water and Sanitation Program reported on FSM in 12 cities in Africa, Latin America, South Asia, and East Asia along the entire service chain (Scott et al., 2014). According to this study, 64% of the excreta in these cities were processed by onsite sanitation technologies but only 22% was safely managed. The study result also showed that 42% of excreta from onsite sanitation technologies are directly discharged into the urban environment

Thus, FSM which is required for one-third of the global population has not yet been addressed for the majority of people using onsite sanitation technologies. The result is direct discharge in the environment with significant deterioration of human and public health (Scott et al., 2014).

2.3.2 Finding proper solutions to the current FSM challenges

It is necessary to improve and find appropriate strategies and solutions in FS management that deals with both unplanned and planned urban and peri-urban development, institutional settings, eligibility and expected future sanitation infrastructure and service provision. (WSP, 2016)

In short, an FS management concept should be based on the assessment of existing sanitary infrastructure and trends (WSP, 2016)

- current FS management practices and their shortcomings
- stakeholder customs, needs, and perceptions regarding FS management and use
- environmental sanitation strategy
- prevailing socio-economic, institutional, legal and technical conditions, and
- the general urban development concept

Based on an FS management concept, FS treatment objectives may then be formulated and, consequently, feasible treatment options be evaluated. In most places, a large array of technical, economic and institutional/organizational measures are required to improve the FS management situation

2.3.3 Sanitation service chain

The sanitation service chain (SSC) describes the complete chain of movement that FS and wastewater follow from point of origin and capture to the final point of disposal and or reuse. When conventional sewerage is used, the SSC follows the movement of the wastewater from the point of flushing through the sewer network to the treatment plant and point of final disposal of the end products of treatment (SFD-PI, 2017a). When referring to FSM, the sanitation service chain comprises containment of fecal matter, emptying of the containment, collection for transportation, treatment of the FS and end-use or disposal of FS end products (SED-PI, 2015a). Each of these components of the FSM service chain forms a crucial component for the successful implementation of FSM. The definition of the SSC has changed from the narrower perspective of the MDG era focused on containment to a more holistic approach which encompasses the movement of FS from containment to disposal (Blackett & Evans, 2015). A representation of the SSC with these factors considered is illustrated in Figure 2.

The entire sanitation delivery chain (containment, emptying, transport, treatment, and disposal/reuse) must be examined in order to ensure a separation of human contact from human excreta within and beyond the household premises (Peal et al., 2015). The main purpose of sanitation is to prevent the transmission of fecal-borne disease and reduce the risk of environmental contamination.

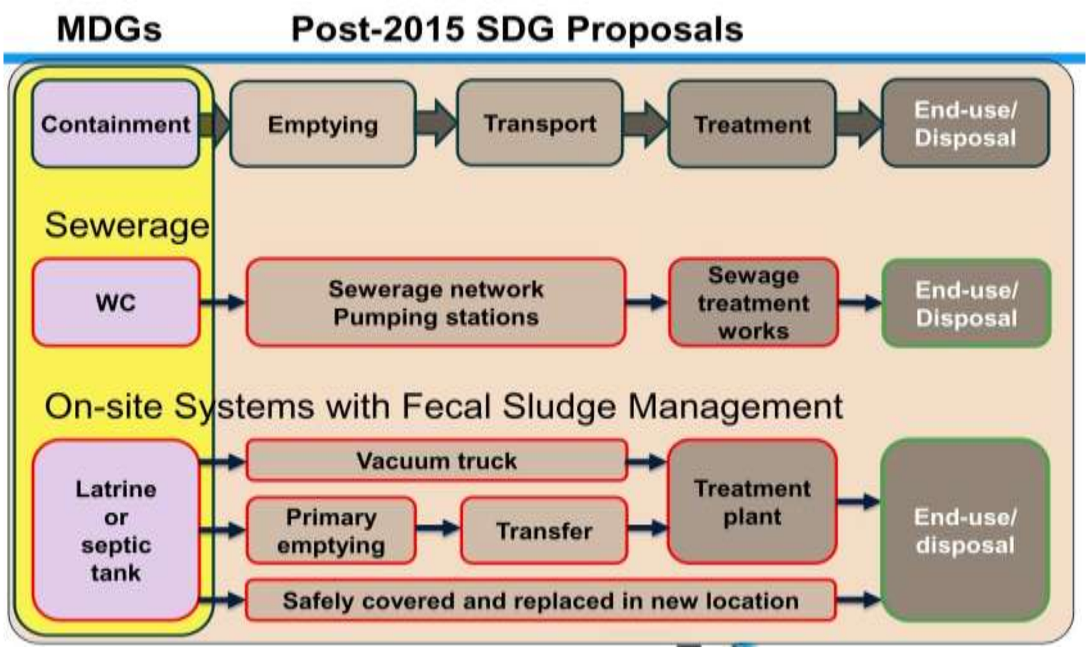


Figure 2: SSC of on-site sanitation and sewerage system technologies (WSP, 2016)

A. Containment (on-site and off-site sanitation)

The structure that stores the excreta and black water mainly comes from the toilet worldwide as containment. In the FSM process, the initial parts are the containment of human excreta. Containment is the act or condition of containing. So, containment of human sludge means the containing of human sludge or excreta and the wastewater. While global monitoring currently focuses especially on the type of sanitation technology used by the household, there is a need to understand what happens with human excreta beyond the point of containment (Peal et al., 2015). Containment facilities are typically developed by the household owners if they are private or a community if shared (Peal et al., 2015). At this point, if it is not well contained, it can contaminate the environment.

The aims of containment are to remove the wastewater and excreta from households. It will either combine technology for collecting excreta only, with technology for wastewater collection or option for technologies that collect and treat all wastewater and excreta (Monvois et al., 2010). The range of technologies that can be considered and identified by the SFD Graphic Generator are:

- No on-site container,
- Septic tank, fully lined tank (sealed),
- Lined tank with impermeable walls and open bottom,
- Lined pit with semi-permeable walls and open bottom,
- Unlined pit,
- Pit (all types), never emptied but abandoned when full and covered with soil,
- Pit (all types), never emptied and abandoned when full but NOT adequately covered
- Toilet failed, damaged, collapsed or flooded,
- Containment (septic tank or tank or pit latrine) failed, damaged, collapsed/flooded
- No toilet/Open defecation (SFD-PI, 2017a).

Those containment technologies may be connected to one or more of the following: To a centralized or decentralized combined sewer, to a centralized or decentralized foul/separate sewer, to a soak pit, an open drain or storm sewer, waterbody and open ground (SFD-PI, 2017a).

B. Faecal Sludge Emptying and transport

Emptying is the removal of FS from the containment and is usually in conjunction with a transportation method that looks at the movement of the FS from the point of origin to a treatment or disposal facility. Collection can be by mechanical means or manual means. An example of manual means includes the use of shovels by scavengers or manual Laboure while mechanical means include a vacuum truck or sludge gulper (Strande et al., 2014). The predominance of on-site sanitation means that pit or tank emptying is required at regular intervals. Household pit and septic tank emptying behavior is not well understood or characterized in the literature (Williams, 2015).

Emptying Methods of Fecal Sludge

The prevailing methods used around the developing world for emptying septic tanks or pit latrines can be categorized into three main groups: manual, manually driven mechanical system, specifically designed mechanical systems (Kone *et al.*, 2007). It can help to identify the suitable option for septage removal from tanks/pits. The general The emptying process or techniques are shown in Figure 3 below.

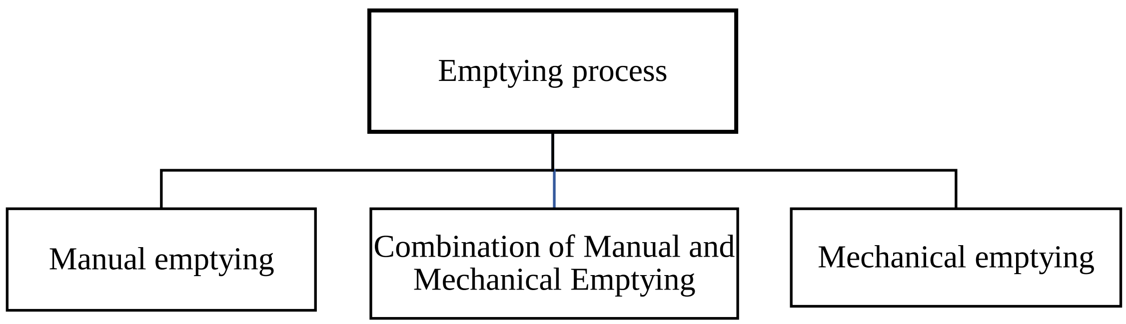


Figure 3: Sludge emptying method

Manual and motorized emptying and transport systems

Manual and motorized emptying and transport refer to the different ways by which fecal sludge can be removed from the facility location.

Manual emptying of pits, vaults, and tanks can be done in one of two ways: (WHO, 2018)

- Using buckets and shovels; or
- Using a portable, manually operated sludge pump (while this may be mechanized, it still requires manual/physical handling)

Motorized emptying and transport (also known as mechanical emptying and transport) refer to the use of any vehicle or device equipped with a motorized pump and a storage tank for emptying and transporting fecal sludge. People are required to operate the pump and maneuver the hose, but the fecal sludge is not manually lifted or transported. Wet systems such as septic tanks and fully lined tanks are commonly emptied using motorized emptying and transport. (WHO, 2018)

Many developing countries are struggling to find viable technological and business solutions to pit and septic tank emptying without which the gains of improved sanitation coverage fail to bring desirable benefits (Chowdhary and Kone, 2012). There are considerable knowledge gaps about fecal sludge emptying as a service, and its effectiveness as a component or an integrated part of the city's sanitation service provision (Chowdhary and Kone, 2012).

Risks Associated with the Manual Emptying

The costs for emptying services are again usually borne by the facility users (Peal et al., 2015). The manual type of emptying, although preferred in low-income neighborhoods, is generally considered an illegal activity by local authorities. This could be in response to the environmental pollution that occurs when manually emptied sludge is indiscriminately disposed of in drains, water bodies or dug into shallow holes. Ideally, once collected, sludge has to be delivered to a treatment facility where it can be stabilized so it does not become an environmental nuisance or pose to health hazards (Medland et al., 2016).

C. Fecal sludge treatment and disposal/end-use

Different treatment processes are employed depending on the characteristics of the incoming FS as well as the intended disposal methods of the end products. Examples are planted drying beds or vermicomposting (Strande et al., 2014). Consequently, treatment may produce useful end products for resource recovery e.g. fertilizers. This part of the SSC is usually the mandate of the local authority or private companies under contract from the government (Medland et al., 2016). All in all, the SSC requires all these processes to be fully functional hence the need for the integrated systems approach incorporating the technological, management and planning aspects (Peal et al., 2015). Not one of the three aspects must be treated in isolation if a successful FSM strategy is to be implemented and maintained. When all three components are considered holistically and not in isolation, the untreated FS can be moved away from the community and safely treated. However, planning and management aspects are not always observed in service delivery, with focus only on the technologies (Strande et al., 2014).

At this stage, a description of all treatment facilities (wastewater and fecal sludge), including influent and effluent volumes of wastewater treatment, input and output volumes of fecal sludge treatment, scale (capacity of the treatment plant – as compared to the volumes received and treated), operation and maintenance issues, and extent of treatment provided (that is the percentage of wastewater or fecal sludge that is considered as treated) should be considered. In addition, a general assessment of the quality, effectiveness, and functionality and performance standards of treatment facilities is to be included, where appropriate to the context (eawag, 2018).

2.4 Excreta/Shit Flow Diagram (SFD)

The excreta flow diagram or shit flow diagram or SFD as it is popularly known is a diagrammatic representation of the flow of excreta in a city or within a defined region from its point of containment to its final destination (Scott et al., 2016). The SFD is a result of a project analyzing the management of fecal sludge in 12 cities under the Water and Sanitation Program (WSP) of the World Bank (WB) (Blackett & Evans, 2015). The SFD graphic shows the movement of fecal sludge from the point of generation as it follows the SSC to its point of disposal or end-use. The SFD graphic is accompanied by a report that highlights the various aspects of the enabling environment drawn from the service delivery context of the city (SFD-PI, 2017a). The SFD follows the SDG focus of the safe management of excreta hence the distinction made on-site and off-site systems and or sewered and non-sewered systems (eawag, 2018).

The SFD methodology was developed by Blackett & Heymans, (2014) to assess sanitation on a city-wide scale in 12 cities under the WSP project. Since its development and introduction, the tool has been adopted and expanded as seen by the publication of 47 SFDs on the SFD website (SFD-PI, 2017b). The SFD has been described by users as "a powerful tool to communicate and visualize how excreta physically flows through a city or town, which clearly differentiates between safe and unsafe management. SFDs are helpful advocacy and assessment tools because they are easily understood by non-experts and decision-makers" (Lüthi et al., 2017). A summary of what to expect and not to expect from the SFD is given in Box 2.1.

Box 2.1: What exactly is an SFD?

1. What is an SFD

- It is an effective communications and advocacy tool - A tool for engineers, planners and decision makers - Based on contributing populations and an indication of where their excreta go
- A representation of public health hazard
- An overview from which to develop sanitation priorities

2. What is NOT an SFD

- Based on volumes/mas – these are determined by other related factors-
- A representation of public health risk (risk = hazard x behavior)
- A precise scientific analytical tool Source: (Blackett & Evans, 2015)

Shit Flow Diagram Promotion Initiative (SFD-PI) is coordinated by SuSaNa (Sustainable Sanitation Alliance) with numerous partners. The SFD-PI is making continuous efforts to improve the SFD and its website which is now a repository for SFD reports from various countries. In addition, the "SFD toolbox" is available on the website which contains the graphic generator tool, templates, and guidelines for the production of SFDs (Blackett & Evans, 2015). SFD can only be placed on the public domain after being checked for quality control purposes (Blackett & Evans, 2015). The SFD toolbox provides guidelines and templates which can be used in the preparation of an SFD for a city to ensure uniformity and a standardized end product (Blackett et al., 2014). From the toolbox, SFD manual details the methodology for the collection of the requisite data required to compile the SFD graphic and context delivery report. In addition, it also provides some templates to guide the preparation of the report as well as the graphic generator for the SFD graphic. (SFD-PI, 2017a).

2.4.1 Methods and data sources

The SFD graphic generator has four steps involved in its use as detailed by the SFD-PI, (2018). First, it has a section to allow input of basic city-data. Next, it has a groundwater assessment tool that helps to determine the risk to groundwater pollution considering parameters such as soil type, depth to the water table and distance of water source to latrines. Additionally, there is a selection grid from which the appropriate technologies used in the city are selected and used to build a matrix into which data regards the proportion of the population making use of the various technologies along the SSC is added. In this way, the proportions of excreta are calculated and distributed as either safely or not safely managed to depend on the proportion which is emptied, transported and treated (SFD-PI, 2017a).

Data sources used to develop SFDs can include household surveys, key informant interviews, secondary literature, focus group discussion and observation or measurements at treatment facilities (Figure 4).

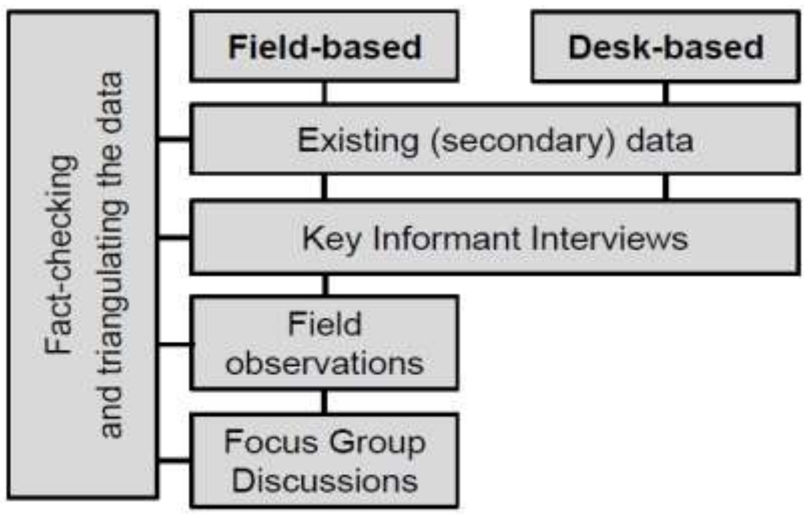


Figure 4: Methods of data collection for SFD

The more reliable the underlying data, and the greater confidence decision-makers have in that data, the more likely they are to act on the basis of what it shows. There is, therefore, a relationship between SFD accuracy and credibility (Blackett & Evans, 2015).

The SFD graphic is accompanied by the service delivery context report which provides information with regards to the basic information about the city, institutional roles, associated policies and information about budgets, quality and quantity of services, all feeding into the enabling environment. This information can be analyzed to see where the weaknesses lie in the service delivery context so as to allow for action points to be drawn up. Thus, the report provides the basis to carry out a city service delivery assessment.

2.4.2 Shit Flow Diagram (SFD) with other FSM diagnostic tools

The SFD is the starting point of any analysis. It helps set the scene for identifying the scale of the problem and explaining it in terms of the sanitation service chain. Analysis of other tools is then linked to that, in particular (Scott et al., 2016).

City Service Delivery Assessment (CSDA) – this identifies weaknesses in operationalizing the service chain which delivers the outcomes.

- ☞ Public Health Risk Assessment – risk-based approaches identify which areas of the sanitation chain are of the highest risk to public health.
- ☞ Quantification and characterization – while the SFD is designed in terms of proportions of households, deriving as it does from household survey data primarily, it is implying volumes.
- ☞ Intervention options assessment – the twin SFDs are also the starting point for intervention options assessment, as any sensible analysis should begin from an understanding of the problem, its scale, and nature.

2.5 Faecal Sludge Management Related to Health Hazards

The risk of infection from exposure to fecal contamination is a combination of the likelihood of exposure to the hazard and the impact of the pathogen hazard itself on the person exposed (WHO, 2015). The hazard itself does not present a risk if there is no exposure to it (Box 2.2). Reducing the risk from fecal contamination is therefore about reducing the fecal pathogen hazard level (i.e. concentration or numbers of the pathogen) and/or reducing exposure to the hazard of a potential human host (Mills et al., 2018). Box 2.2 shows that some of the definitions that interlinked with health hazards and its exposure (risk) due to improper fecal sludge management practices.

Box 2.2 Definitions (WHO and UNICEF, 2015)

Risk: The likelihood and consequences that something with a negative impact will occur.

Hazard: A biological, chemical or physical constituent that can cause harm to human health.

Hazardous event: any incident or situation that introduces or releases the hazard (i.e. faecal pathogens) to the environment in which people are living or working, or amplifies the concentration of the hazard in the environment in which people are living or working, or fails to remove the hazard from the human environment.

2.5.1 Hazardous events, control measures, and exposure groups

Control measures are defined as any barrier or action that can be used to prevent or eliminate a sanitation-related hazardous event or reduce it to an acceptable level of risk.

The people most likely to be exposed belong within one of four risk groups: (WHO, 2018).

- **Sanitation system users:** all people who use a toilet.
- **Local community:** people who live and/or work nearby (i.e. people who are not necessarily users of the sanitation system) and may be exposed.
- **Wider community:** the wider population (e.g. farmers, lower-lying communities) who are exposed to (e.g. through recreation or flooding) or use sanitation end-use products (e.g. compost, fecal sludge, wastewater) or consume products (e.g. fish, crops) that are produced using sanitation end-use products intentionally or unintentionally, and may be exposed.
- **Sanitation workers:** all people – formally employed or informally engaged - responsible for maintaining, cleaning or operating (e.g. emptying) a toilet or equipment (e.g. pumps, vehicles) at any step of the sanitation service chain.

2.5.2 Risk exposures at the containment technologies

Fecal sludge, for example, should be contained in an impermeable technology (such as a septic tank) or in a permeable technology such as a wet-pit that leach directly into the subsoil. In either case, sludge should not enter the environment where it could directly expose users and the local community to fecal pathogens(UNESCO-IHE, 2014). The liquid effluent from an impermeable container should discharge to a sewer or subsoil structures via a soak pit or leach field or should be fully contained for later conveyance. It should not be discharged to an open drain or water body where, through contact or consumption, it could result in the exposure of the local community or wider community to fecal pathogens (WHO, 2018).

Where leachate from permeable technologies or effluent from impermeable technologies leaches into subsoil structures, there is a risk that groundwater and nearby surface water could be polluted, potentially contaminating local water sources used for drinking and domestic tasks (e.g. dishwashing). If groundwater is not used for domestic purposes and other safe drinking-water sources are available, then the risk from groundwater will be lower but may still pose a risk if groundwater is occasionally used (e.g. when the safe source is unavailable or unaffordable) (WHO, 2018).

As shown in Figure 5, the common hazardous events in pit latrine containment technologies are leachate from the facility into groundwater source and pit overflows to the local environment. Hazardous events from septic tank containment technologies are also shown in Figure 5; septic tank overflows, an effluent outlet to open drain or water body, leakage from a crack or damaged septic tank to groundwater and effluent outlet to groundwater via soak pit or leach field as.

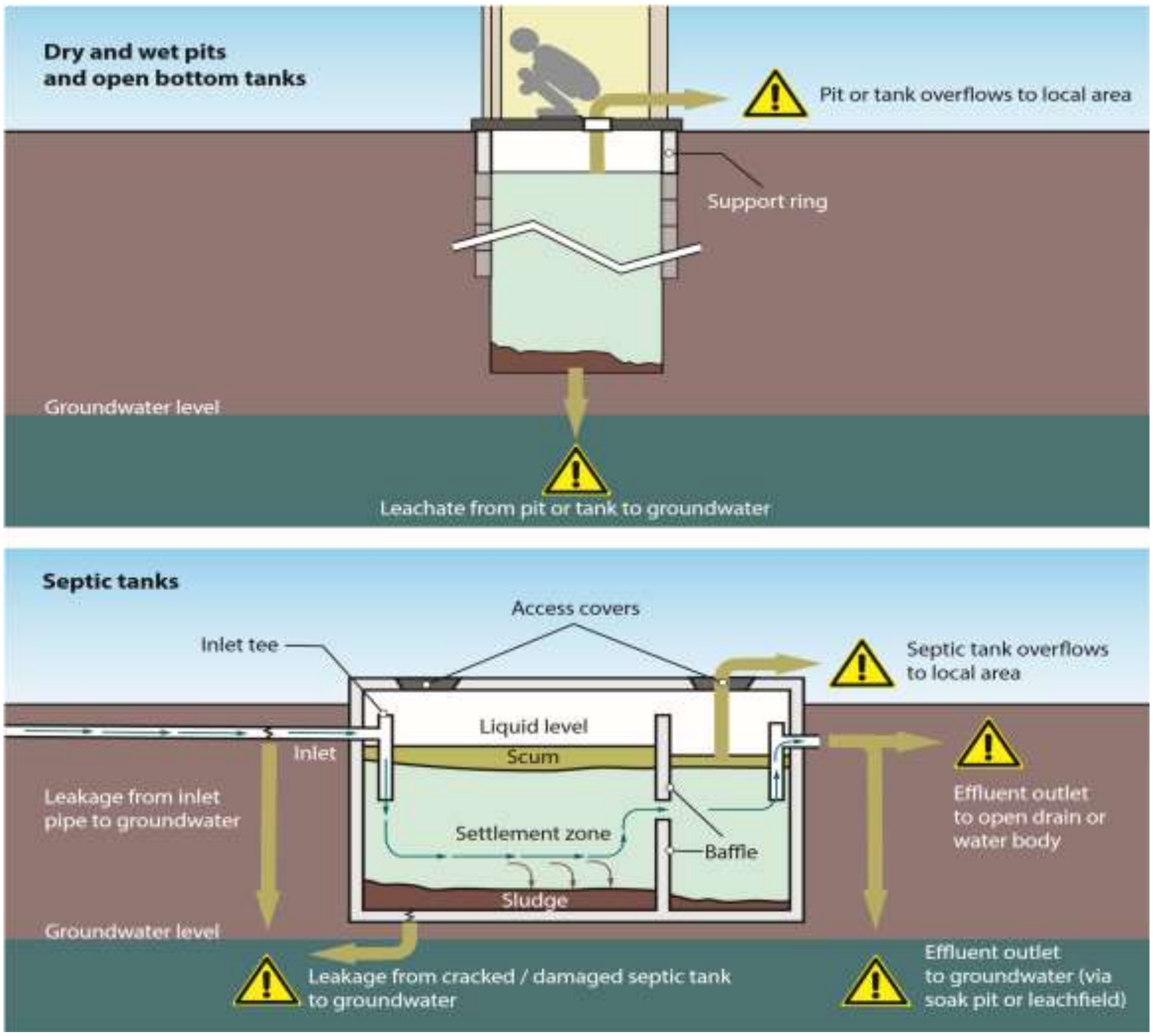


Figure 5: Hazardous events for different containment technologies (WHO, 2018)

2.5.3 Risk exposures at the conveyance stage

Conveyance refers to the deliberate movement of wastewater or fecal sludge from a containment technology to offsite treatment, and/or end-use/ disposal. Conveyance systems can be sewer-based or based on manual or motorized emptying and transport (Tilley et al., 2014). Manual and motorized emptying and transport refer to the different ways by which fecal sludge can be removed from the facility location. Both manual and motorized technologies require workers (service providers, emptiers, desludges, and exhausters) to handle tools and equipment that have contact with fecal sludges (including the liquid supernatant or effluent if any) Workers entering pits should be avoided due to the risk of injury or death from pits collapsing or inhalation of toxic gases (UNESCO-IHE, 2014). Emptying may put the users and community at unacceptable risks resulting from exposure to spillage as the work proceeds. The key principle for safe emptying and transport is, therefore, limiting the exposure of these groups to the hazardous fecal sludge (WHO, 2018).

As Figure 6 indicated, hazardous events from unsafe FS emptying practices are workers contact during manual handling and transport, worker contact during mechanical emptying, and FS discharge without treatment into open drains/water bodies or open ground.

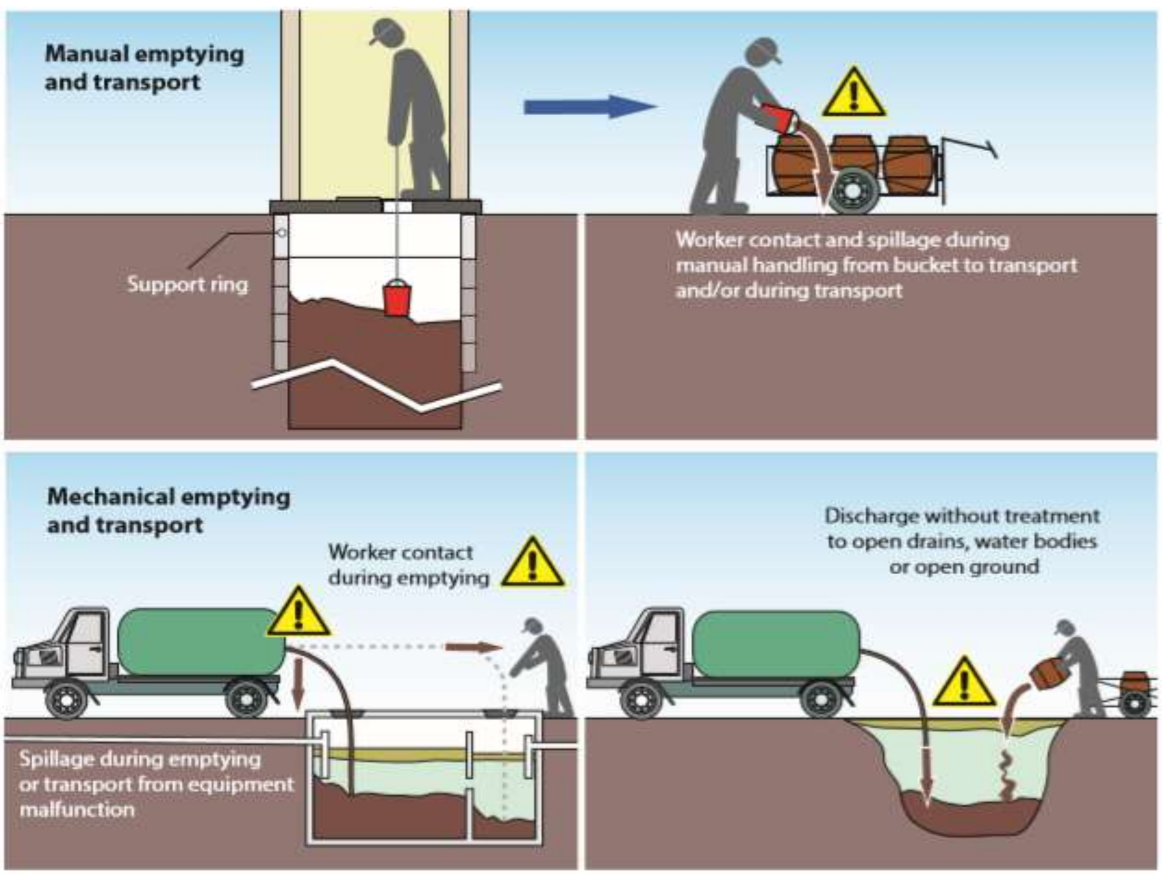


Figure 6: Hazardous events for conveyance technologies (WHO, 2018)

2.6 Community-Led Urban Environmental Sanitation

Intensive field-testing and validation of the Household-Centered Environmental Sanitation (HCES) planning approach was conducted between 2006 and 2010 in seven different urban and peri-urban settings in Africa, Asia, and Latin America. The experience and lessons learned from these pilot projects were used to develop a revised set of planning guidelines called Community-Led Urban Environmental Sanitation (CLUES) (Lüthi et al., 2011a). The name change from HCES to CLUES highlights the importance of broad community involvement (beyond the household level) in the planning and decision-making processes. Although the name has changed, the basic characteristics remain the same and multidisciplinary and multi-disciplinary actor approaches emphasizing early involvement of all stakeholders in the planning process (Lüthi et al., 2011).

Some of the strengths of the planning approach: CLUES adopt a flexible and neutral approach with regard to technology choice, taking into account economic factors (ability and willingness to pay) and social benefits such as privacy, dignity, and convenience. Its objective is to link the expression of needs at the community level with those resources available locally and those requiring additional inputs from external agencies (Lüthi et al., 2011b). The approach combines expert knowledge at the national and municipal levels with local knowledge at the community level. CLUES is primarily focused on solving sanitation problems in unserved (often informal) settlements. Its objective is to derive solutions requiring minimum external support and, at the same time, complementing citywide and strategic approaches(Lüthi et al., 2011b)

3. MATERIALS AND METHODS

3.1 Study Area Description

3.1.1 Location and Topography

Kombolcha town is located in the South Wollo Zone of the Amhara Region, a north-central part of Ethiopia. The town is found at about 377 km north of Addis Ababa (the capital city of Ethiopia) and 505 km from Bahr Dar City, the Amhara region capital. Kombolcha is occasionally described as the twin city of Dessie, which lies 23 km to the North-West. The geographical location of the town is about 11^0 6'N latitude and 39^0 45'E longitudes. The elevation of the town ranges from 1600 to 2700 meters above sea level while its landscape is about 45.5% flat surface, 21.5% hilly/undulating, 32.9% mountainous and the remaining 0.6% is a valley (Kombolcha town administration, 2018). Kombolcha town is currently divided into 12 administrative Kebeles which are 6 rural and 6 urban kebeles with 40 ketenas. Figure 7 shows the location map of the Amhara region, South Wollo Zone, Kombolcha town, and the study area (with 6 administrative kebeles) respectively.

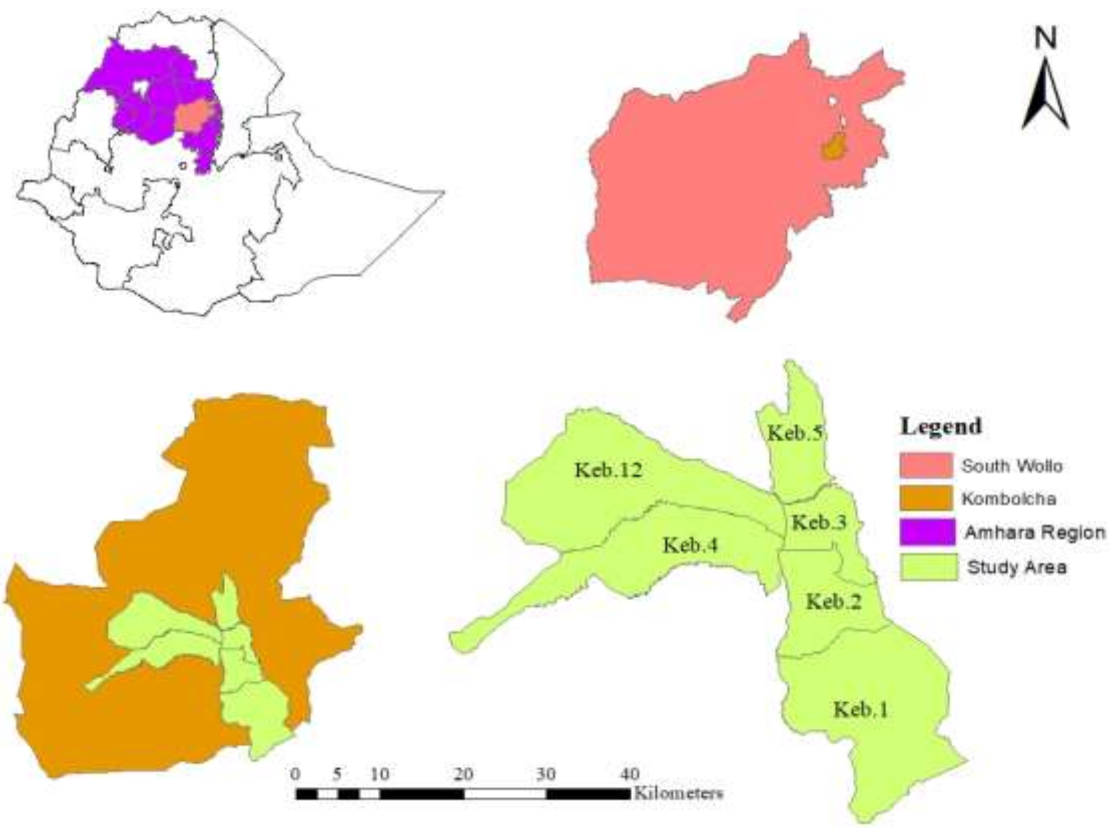


Figure 7: Location map of Kombolcha town

3.1.2 Climate

According to Kombolcha town metrological station data, the city receives a mean annual rainfall of 1,027 mm which is characterized by bi-modal distribution, with two rainy and two dry seasons occurring intermittently. The long rainy season extends from June to mid-September, which supports the major that contributes the most of the annual rainfall. The shorter rainy season comes in March and April. The annual monthly minimum and maximum rainfall are recorded 19 mm and 253 mm in December and July respectively. The annual monthly mean minimum and maximum temperatures are about 11.3^0c and 25.8^0c respectively. The annual daily mean temperature is about 19.6^0c. according to Kombolcha Meteorology station data as shown in (Appendix 3, Table 12).

3.1.3 Soil characteristics

There is a strong relation between landform and soil characteristics. The study area has various landforms. As per the variety of landforms within the study area, the soil characteristics are diverse for most of the mapping units.

There are three different soil types in the study area which are Eutric Cambisols, Eutric Regosols, and Lithosols. The area covered by these soil types is 1667 ha, 180 ha, and 70 ha, respectively. The dominant major soil is Cambisols (87%) followed by Regosols (9.4%) and the remaining 3.6% is Lithosols. The major soil textures in the study area are clay and clay loam. Those significant soil characteristics such as soil type, major soils, and soil textures were taken from the Ministry of water and energy.

The soil type is the principal determinant of groundwater contamination risk. As a result, the soil type along with the study area for different clusters was mapped as can be seen from Figure 10A. As Figure 10 has shown, in kebele 12 cluster 9, the soil types are Regosols and Cambisoles; whereas, the soil texture is clay loam. For kebele 3 and 2, the particular soil types are Cambisols, Regosols, and Lithosols. Their respective soil texture is also clay as shown in Figure 10(B).

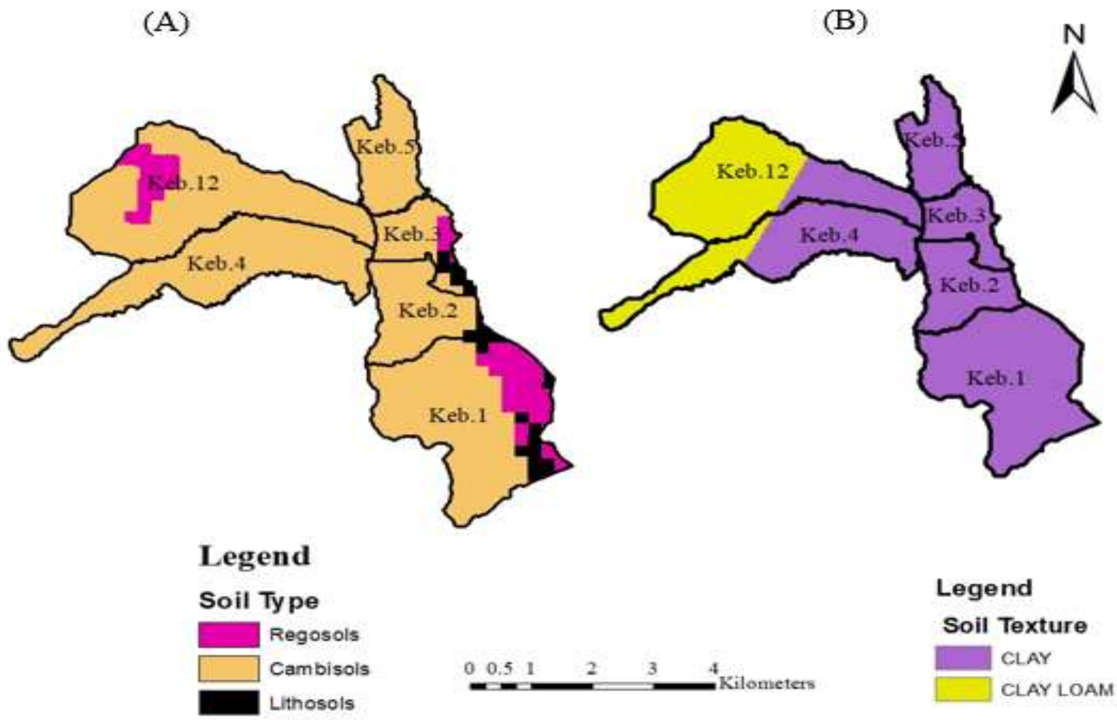


Figure 8: Map of (A) Soil type; (B) Soil texture

3.1.4 Population and Housing conditions

According to the town Administration, the population has grown to 143 637 in 2018/19 for both rural and urban kebeles of the town. Approximately 23 percent of the population lives in rural areas, and 77% in urban areas. The urban kebele population was estimated at about 110,654 with 50,860 women and 59,794 men.

In terms of the age structure of the urban population of the city, 65.4% of the population is between the age of 15-64, 29.6% under the age of 14 and 5% over 65 years. Thus, the proportion of dependency due to age is 29.6% for children and 5% for elders. Thus, the age-dependency of the community is up to 34.6 percent.

The housing conditions of the town fall under kebele rental, kuteba, private rental and owner-occupied housing categories. The number of rental Kebele houses which is occupied by low-income households is about 379. The remaining number of private, kuteba and condominium houses are counted about 7722, 931 and 1545, respectively (Kombolcha Town administration, 2018).

3.1.5 Water supply and Sanitation

I. Water supply

The source of water supply for the whole town is groundwater from 9 boreholes of Dewey, Shehshabir and Biraro well fields with a total yield of 320 l/sec. There are also a number of boreholes owned by both private and governmental institutions for domestic, and industrial purposes. Most of these boreholes from industrial establishments are equipped with motorized pumps.

According to Kombolcha town water supply and sewerage authority (2018), the town's overall municipal water supply coverage was 90%. Similarly, the town's overall municipal water supply coverage excluding supplied water through public fountains is about 65% (57 liters per person per day) when compared with GTP 2 (KTWSSA, 2019).

Currently, following the expansion of numerous industries, the Kombolcha town population is extremely increasing. Likewise, the town’s industrial water demand is increasing day in day out. To adjust this challenge, the town has recently inaugurated 500 million Birr worth water supply projects that can provide a potable water supply for more than 250, 000 citizens and cover 50% of water demand of 40 industries for the next ten years (KTWSSA, 2019).

II. Solid waste management

Kombolcha town is one of the few industrial and fast-growing cities in the northern parts of Ethiopia. The fast growth of the population related to various industrial investitures results in a huge generation of solid waste in the municipality. Consequently, the town’s administration owns the properly designed and constructed landfill site in 2008 so as to provide efficient solid waste management services. However, solid waste management becomes a challenging task in recent years due to institutional constraints such as lack of public awareness, weak regulation, and controlling mechanism (KTSBD, 2019).

Kombucha town’s solid waste management was being paid a little devotion. As the result, the town is facing environmental degradation and public health risks due to uncollected disposal of waste on the streets, market places, drainage canals, and riversides by indiscriminately dumped waste and pollution of water resources (Yimer & Sahu, 2014). The town population generates on average a total of 11,229.2 kg of solid waste per day;

whereas, the average rate per person is about 0.179 kg. The composition of daily household's solid waste is 52.61% food waste, 20.9% ash and dirt, 17.65%-yard wastes and the remaining 4.63% are recyclable items. Furthermore, 72.5 % of these households are getting solid waste collection services by the primary collection organizations established by the small and micro-enterprise groups and the rest of the households disposed of their waste either on a shared container and/or open spaces like river Borkena (Yimer & Sahu, 2014).

III. Liquid waste management

Currently, the town has a fecal waste treatment plant constructed in 2008 with Entricklungs Bank of Germany and Kombolcha town administration with the assistance of the Ministry of Works and Urban Development co-financed budget. Presently, the plant is receiving fecal sludge from Kombolcha town, Dessie and other neighboring towns. The fecal sludge disposal is practiced by the municipality and private vacuumed trucks to remove the sludge at the specified plant site (KTWSSA, 2019).

There are two councils in Kombolcha town, water, and sewerage service authority and sanitation and beautification department which are primarily responsible in operation, maintenance, control and development of water and sanitation services (solid and liquid waste) in the municipality. Related to fecal sludge management, there are three toilet types of facilities or technologies in the municipality which are flush toilets, VIP latrines, and simple pit latrines. According to the Kombolcha town health department (2019) report, the current Kombolcha town urban kebeles toilet technologies based on the improved and unimproved basis are 91% and 9%, respectively. The percentage values for every 6 urban kebeles are presented in Table 13 (Appendix 3). Based on the health office department definition, unimproved toilet facilities are open pits (traditional latrines) that had no roof (plastic roof), temporary/non-permanent wall and wood slab or no slab at all.

There is no recorded data related with shared/private toilet facilities in percentage of flush, VIP and pit latrine technologies, except CSA 2007; housing units and their respective types of toilet facility census result, that showed of all 15,261 housing units 3505 (23%) have no toilet facility whereas (5.6%), (11.6%) and (59.8%) of housing units have shared or private flush toilets, VIP latrines, and pit latrine technologies respectively.

3.2 Research Design

The research design is primarily based on the SFD tool that already exists and processed by the Shit Flow Diagram Promotion Initiative (SFD-PI) which is found under the set of diagnostic tools developed by the World Bank (Scott et al., 2016). Thus, the framework for data collection is based on the SFD methodology framework for FSM diagnostics (Scott et al., 2016). Subsequently, FSM gaps and public health risk exposure, as well as community perception mapping regarding the current fecal sludge management services, have been assessed following the results of the SFD tool, with the purpose of understanding the current FS management patterns and future scenarios as well as community remarks.

This SFD methodology was selected because the study objective focusses on fecal sludge management that in line with its objective as well as is a current worldwide advocating and systematic way of fecal sludge management assessment tool.

3.3 Data Collection Instruments

The study was proposed to have and used household surveys, field observation, key informant interviews (KII), focus group discussions (FGD), and document review, data collection instruments. The detailed checklists and questionnaires prepared for the study have been attached as Appendix 1 and 2 of this research.

3.3.1 Document review

It was important to conduct a document review with the intention of gathering all the relevant data looked-for the research to be abundantly informed and completed. Documents were gathered from various sources such as relevant journals, conference proceedings, academic thesis, organizations, and donor reports, official records or reports and maps from Kombolcha town respective administrative layers, SuSaNa website, key informants and sanitation professionals working in Kombolcha town.

The review initially helped in gaining some of the key stakeholders to engage and secondly to triangulate data and fill in gaps. Likewise, the review was helpful in understanding the current sanitation situations of Kombolcha town and the methodology used to develop SFD.

3.3.2 Household survey

The purpose of the household survey was to determine household characteristics and fecal sludge management arrangements of households. Questionnaires were developed with 58 questions and more than 25% of answers were gathered through observation by enumerators (a researcher). The household questionnaire included 58 questions under the following five components:

- Household Characteristics
- Sanitation situation (Technologies, containment arrangements & emptying practice)
- Community's Perception concerning FSM
- Hygiene practice and incidents of diseases
- Level of Satisfaction and intention for future planning

a) Sampling

Among the 12 administrative Kebeles, this research was conducted for only 6 urban kebeles. A stratified sampling method was also used for this research in order to draw sample households for data collection. A stratified sampling method ensures spatial randomness, social equity and takes into consideration density, geographical randomness, and housing types. Moreover, purposive sampling was conducted in stakeholder identification and key informant interview process. Major steps that have been followed during sampling were:

I. Cluster Identification/Stratification

Kebeles are the primary administrative division within the Kombolcha town and ketenas are the smallest administrative unit. There are population and household data for kebeles and ketenas. A list of the 40 ketenas was collected from all the 6 urban kebeles. In cases where adjacent ketenas were found to be similar in terms of population density, land use composition, and built-form, they were merged to generate a cluster after reconnaissance survey. Therefore, 9 clusters were identified for this study as shown in Figure 11.

As ketenas located in each cluster have homogenous characteristics, taking one/two ketenas from each cluster can be representative. Then, the researcher selected two ketenas from each cluster except cluster 9 which has distinct characteristics only one ketena, using a random sampling method to conduct the survey.

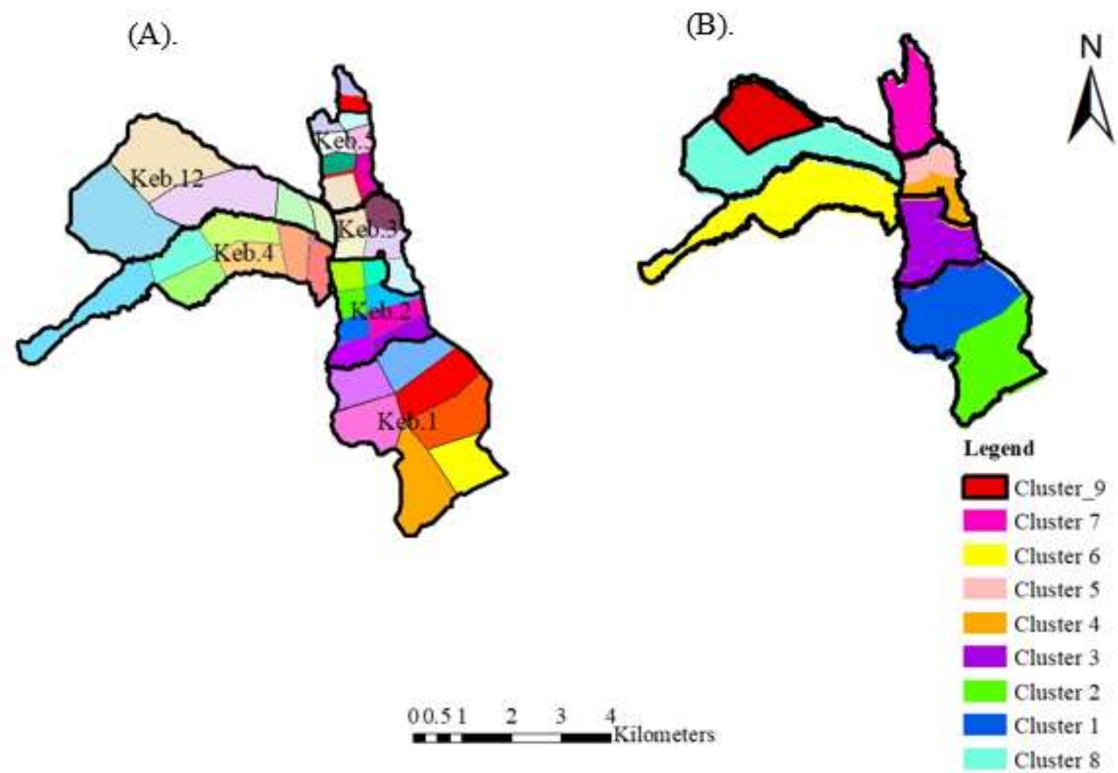


Figure 9: Map of (A) kebele boundaries & respective ketenas; (B) Identified clusters

II. Sample Size Determination

In designing a sample size determination, sample sizes were determined by considering financial constraints, time and representativeness (such as level of confidence or risk, level of precision and the degree of variability).

Based on the above considerations in addition to the purpose of the study and population size, 95% confidence level, ±5% precision and 80% proportion variability was adopted and the sample size was determined using proved scientific statistical formula (Dean et al., 2013).

$$\boldsymbol{n} = \frac{[\boldsymbol{Np}(\mathbf{1}-\boldsymbol{p})]}{[(\mathbf{e^2}/\mathbf{Z^2} * (\mathbf{N}-\mathbf{1})\ + \mathbf{p} * (\mathbf{1}-\mathbf{p})]}$$

Where,

- n = the required sample size
- N = Total number of household units (sample frame i.e. 22984 in Table 1 below)
- Z = standard normal deviation at the required confidence level that corresponds to a 95% confidence interval equal to 1.96

- e = the level of statistical significance (Allowable error) (0.05)
- P = the proportion in the targeted population estimated to have characteristics being measured (from previous studies or studies in other comparable countries i.e. 0.8 from Scott et al., (2016)

Based on the above formula, n = 243 was drawn for a reliable minimum sample size of households. Finally, by using the proportional allocation method the researcher decided to take sample households from selected ketenas. The distributed sample households in each cluster are presented in table 1. Thus, sample households were selected and the sampling was drawn using a simple random sampling method.

Table 1: Distribution of sample households per cluster

Cluster No	Kebeles and Ketenas	Number of HHs within the cluster	Distributed sample HHs
1.	Kebele 01 ketena 1,2,3 & 4	1577	17
2.	Kebele 01 ketena 5,6 & 7	1657	18
3.	Kebele 02 all 8 ketenas	3562	37
4.	Kebele 03 ketena 1,4&5	2039	22
5.	kebele 03 ketena 2 &3	1158	12
6.	Kebele 04 all 7 ketenas	4785	50
7.	Kebele 05 all 9 ketenas	4867	51
8.	Kebele 12 ketena 1,2,3 &4	2522	27
9.	Kebele 12 ketena 5	817	9
Total		**22984**	**243**

b) Translation and pilot-test of questionnaires

The draft questionnaires were translated into the Amharic language. After completing the first translated draft of the questionnaires, the questionnaires were pre-tested with 10 household interviews. Initial testing was useful to improve the following areas:

- The flow of the questions
- The comprehensiveness of information coverage
- Ease in recording the answers/responses
- Understanding of the Amharic translations
- Length of the questionnaire and its impact on respondent tiredness and response clarity

3.3.3 Key informant interview (KII)

Appropriate checklists were established from which interviews were conducted with key informants (stakeholders) in the sanitation sector to bring to light the present state of management practices of fecal sludge in Kombolcha town related to accomplishments, challenges, and strategies for the way forward along the sanitation service chain.

Generally, 10 key informant interviews (KIIs) were conducted with different stakeholders in the town, such as vacuumed truck driver (private and/or governmental), Water supply and sewerage service office, Kombolcha Town Municipal Authority, Kombolcha town Health Department, Sanitation and beautification department, Kombolcha town health extension workers, Faecal sludge treatment plant supervisor, Faecal sludge treatment plant attendants, Septic tank or pit latrine installers/Masons, and Public toilet attendants to collect a wide range of information regarding the study.

The interviews were carried out by different techniques depending on the informant's available time to talk. Some were on audio calls and most interviews were held face-to-face. The KII checklists are found in Appendix 2 of this document. The duration of the interview varied for different informants due to the scope and content of the questions.

3.3.4 Field observation and transect walk

Visual inspection and observations were embarked along each stage of sanitation service chain (from household containment up to treatment or disposal of fecal sludge) in order to determine the technical requirements of siting sanitation facilities.

The disposal site was also visited to observe the way and manner cesspit emptiers discharge the sludge at the disposal site and also to check the frequency at which they go there, methods used for end-use/disposal of FS, location of water supply source from disposal sites, access for emptying services to pits, septic tanks, risk exposures along the service chain, and sanitation system technologies distribution over the town.

3.3.5 Focus group discussions (FGDs)

The objective of Focus Group Discussions (FGDs) with residents of informal settlements/ slum communities is to gather qualitative data that will complement, validate, or perhaps challenge responses made during the household survey (SFD-PI, 2017a). Accordingly, Two FGDs were held and conducted at the end of the field-based research to understand the town's current situation and to triangulate the data through interaction with a group of community representatives that had been gathered through the preceding steps of KIIs and household survey quantitative data.

The held FGDs were supportive specifically in obtaining more detailed information on the containment systems and emptying practices. The quantitative data collected through a household survey concerning containment technologies were readjusted, especially illegal toilet outlet connections that cannot be addressed through the HHs survey. Likewise, the questions were focused on obtaining data relating to household practices, service levels, past interventions, risks and other issues associated with FSM services that affect their community. Other FGDs discussions with service providers and other stakeholders that had been proposed were not able to appear and held due to their tightened schedule. Topics for (FGD) with community members were based on FSM global study data collection instruments (Scott et al., 2016)

3.4 Data Processing and Analysis

To analyze the collected data, a combination of quantitative and qualitative analysis methods were employed.

3.4.1 Data analysis for production of data tables and graphs

The collected quantitative data from 243 households were analyzed using simple descriptive statistical tools like frequency, mean, and percentages which were operated with Statistical Package for Social Science (SPSS) and Micro Soft Excel for the preparation of data input. The variables have been selected and identified for the preparation of data input. After completing data input, the data were prepared as a tabular form for further analysis.

The qualitative data from key informant interviews (KII), field observations and FGD were compiled and analyzed through the description, narrating and interpreting the situation contextually.

3.4.2 Shit Flow Diagram (SFD) analysis

Fecal waste/shit Flow Diagram is an advocating tool that represents where fecal waste goes, what proportion is effectively managed and where the unmanaged portion ends up. It provides a credible and convincing visual summary of how fecal flows along the sanitation service chain, for a given population, specifically highlighting at which stages the fecal waste becomes ineffectively and effectively managed (WSP, 2016).

The SFD is generally prepared in one of two ways – either through a desk study that relies heavily on secondary data and key interviews or through fieldwork which involves in addition to the former, use of primary data collected through observations and focus group discussions (SFD-PI, 2017a). In the case of this study, a field-based SFD was produced for a detailed analysis of the current situation. The level of SFD was determined on the basis of the following main criteria or requirements:

- ☞ The objective of preparing the SFD
- ☞ The budget available
- ☞ The level of stakeholder engagement
- ☞ How intensely the data analysis was carried out
- ☞ Amount of data collected (SFD-PI, 2017a).

After all, it was determined that an SFD Lite was ideal for this study. That's why an SFD Lite report allows preparing an SFD Graphic with the collected data that focuses on the management of excreta through the sanitation service chain to identify the Service outcomes, rather than service delivery context analysis (SFD-PI, 2017a) which is in line with the objective of this study, fecal sludge management situational assessment.

For this SFD analysis, in addition to the collected data through SFD data collection framework (document review, KII, FGD and Field observations), several key indicators from the household survey were used. Particularly, data from the following pillar household survey questions or parameters were used.

- ☞ "What kind of toilet facility do members of the household usually use?"
- ☞ "Where do the contents of this toilet connected/emptied to?"
- ☞ "What has been done when the pit or septic tank filled-up?"
- ☞ "Where was the fecal sludge emptied into?"

The collected household survey quantitative data was based on the above pillar questions which are the worldwide fecal sludge management, the SFD data collection framework (Scott et al., 2016) in order to gather credible data for this research.

Lastly, the collected data and pre-analyzed data with Micro Soft Excel and SPSS based on the above questions together with their respective percentages of the population and data from SFD data collection framework became an input for Excreta/Shit Flow Diagram (SFD) development.

3.4.3 Groundwater contamination risk analysis

Due to the lack of available groundwater maps or recorded statistics concerning the actual groundwater levels of the town, the estimations were made based on, HH survey, literature review and key informant interviews (KII9).

The risk of groundwater pollution was calculated using the SFD Graphic Generator Groundwater Assessment Helper Tool. The risk of groundwater pollution was estimated from data on drinking water from private groundwater sources, and the distance between groundwater sources and sanitation facilities. The risk of groundwater pollution was assessed according to the following four basic criteria (SFD-PI, 2017a).

1. **The vulnerability of the aquifer:** It was determined based on rock type or soil characteristics in the unsaturated zone and the depth of the groundwater table during the wettest period of the year. The data for soil characteristics were collected from the Amhara region soil map and the depth of groundwater data was determined with the HHs survey.
2. **Lateral spacing between sanitation systems and groundwater sources:** This criterion was evaluated with:
   - ☞ The percentage of sanitation facilities that are located less than 10m from a groundwater source
   - ☞ The percentage of sanitation facilities that are located uphill of a groundwater source.

   Data for lateral separation input was also determined with a personal observation of the facility during the household survey after asked the consents of the owner to see.
3. **Water supply:** It was evaluated based on the percentage of drinking water produced from private/shared groundwater sources rather than piped water from the municipality. The information was gathered via observation in the existence of tap water from the municipality and asking the HHs questions about the purpose of their own water source.

4.**Water production:** This criterion was assessed based on water production technology being used by HHs. The water production technology options were:

- ☞ Protected boreholes, protected dug wells or protected spring where adequate sanitary measures are in place.
- ☞ Unprotected boreholes, dug wells or springs.

The information concerning the water production technologies was gathered through observation of the technology.

3.5 Dealing with the reliability of data sources

Data in this research has been collected from different sources and different methods in order to triangulate data and reduce bias. However, gaps in the quantitative data for the formation of the SFD have been all along the sanitation service chain and, thus, quality issues are discussed as follows.

For a detailed analysis of containment technologies, some of the households were unable to deliver the required information and the published surveys/reports mostly differentiate between different types of user interfaces or between septic tanks and pit latrines, rather than the containment systems below the ground. Therefore, the estimations on septic tank and pit latrine containment systems were based on the KII with pit/septic tank installers (masons) and FGD on some occasions for crosscheck the HHs survey data.

Likewise, when questioned stakeholders about the amounts of fecal sludge transported and disposed at the plant and the plant treatment efficiency, there was an information gap or missing data. In addition, open defecation practice estimation was difficult, even though the wide range of its practice in all parts of the city was a witness. Following this, reasonable/rational estimations or assumption that have been made and discussed at SFD formation sections for credibility and accuracy of SFD.

There was also limited evidence of transportation of FS to land or parts of the town environment before reaching the treatment plant and fecal sludge being removed informally by households themselves. Resulting in the personal estimation, as discussed at the FS transportation session it was difficult to estimate; even though different deliberations made.

Links to the research objectives and methodology used

Table 2 shows the whole objective wise data collection instruments that have been used throughout this research and their link with study-specific objectives so as to achieve the main objective of the study.

Table 2: Objectives and methodology matrix

Research specific objectives	Data Collection Methods for specific objectives
1. To identify existing onsite sanitation technologies in Kombolcha town and assess their management arrangements.	- Visual inspections and observations - Quantitative analysis by HH survey - Key informant interviews (KII)
2. To develop SFD for the current status of fecal sludge management situation and show problems/gaps along each stage of the sanitation service chain	- Qualitative analysis from KII, FGD - Quantitative analysis from HH survey - Visual inspections and observations - Document review
3. To identify public health hazards or risk exposures associated with poor fecal sludge management practices	- Quantitative analysis by HH survey - Focus Group Discussions (FGD) - Transect walk and observations
4. To recognize the public perception of current fecal sludge management practices	- Quantitative analysis by HH survey - Focus Group Discussions (FGD)

4. RESULTS AND DISCUSSION

4.1 Existing Sanitation Arrangements and FSM Practices

Valuation of existing sanitation arrangements and fecal sludge management practices in the Kombolcha municipality was carried on the following segments.

- ☞ House and toilet facility ownership
- ☞ Onsite sanitation technologies and management trends
- ☞ Communal and Public toilets
- ☞ Fecal sludge categories of origin
- ☞ Evacuation and transportation of fecal sludge
- ☞ Treatment and disposal/reuse practices of fecal sludge

4.1.1 House and toilet facility ownership

Out of sampled respondents, 69.1% had their own house. This result was not obtained by asking the respondents randomly from multiple housing within the compound, house owners were the primary choice in the household survey rather than speak loud rented households so as to gather reliable and strong information concerning fecal sludge management arrangements. The private house rented household heads (11.9%) were interviewed when the house owner didn't available during the survey. Again, the interviewed kebele and kuteba house households were 10.3% and 8.7% respectively. Generally, the household survey results identified as 81% of houses private (69.1% + 11.9%) and the remaining 19% of houses were kebele or kuteba houses.

However, the number of housing unit data from Kombolcha town administration, 2018 shows that the number of rental Kebele houses was about 379 and the remaining number of private, kuteba and condominium houses were about 7722, 931 and 1545 respectively. This data shows 87.6% privately owned houses, 3.6% kebele rental houses and 8.8% kuteba houses which somehow differ from the result obtained using HHs survey. The HH survey result also identified 60.1% of private house owners have rental classrooms that constructed tightened with their living house to generate income following the rapid population growth related to the expansion of various industries in the town (Figure 10B). In contrast, the household survey outcome showed that 24.3% of the respondents had access to private household toilets and 75.7% of Kombolcha town inhabitants rely on shared toilets between 2 or more households. This is due to the increase in the construction of rental classrooms with common toilets to generate income following the need for housing in the town. So, out of 75.7% of shared toilet user households, 60.1% was shared between house owners and their rented house households. The remaining 15.6% of households used communal toilets shared between kebele and/or kuteba house user households (Figure 10A).

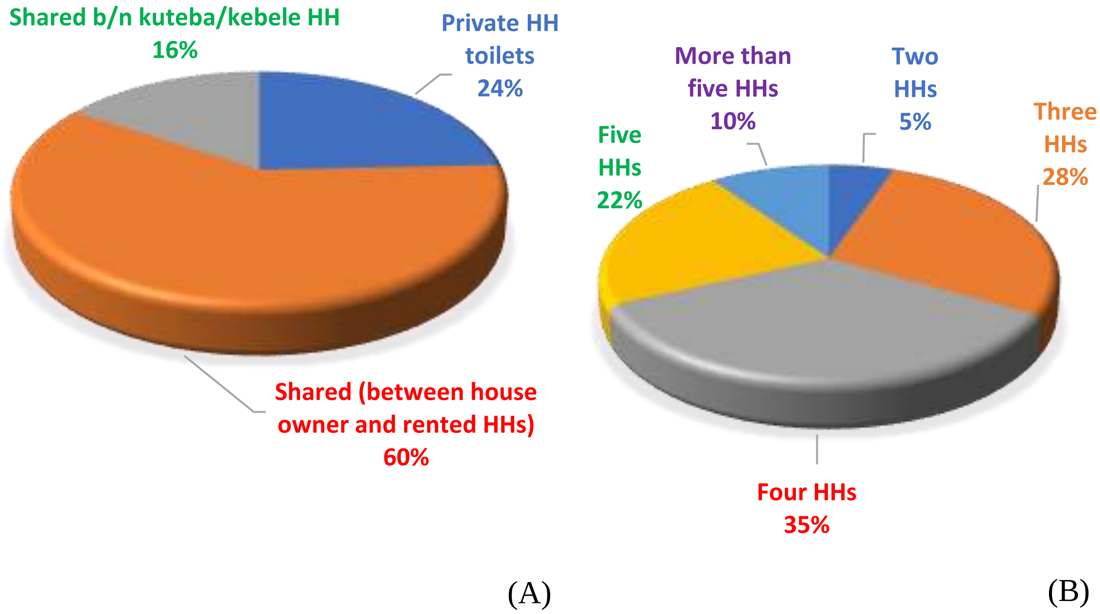


Figure 10: (A) toilet ownership (B) Rented HHs shared a toilet with house owner

Public toilet user households and households without toilet facilities were neither observed nor reported during the household survey. However, public toilets are available in some areas of the town and this is discussed further in the next section.

4.1.2 On-site sanitation Technologies

Household toilets:

The results on the forms of household toilet services used by the sample respondents are presented in figure 4.1 below. The household survey results show that there were mostly five types of household toilets technologies in Kombolcha town. These technologies included cistern flush toilets, pour/manual flush toilets, Ventilated Improved Pit latrine (VIP), pit latrine with and without slab. The highest recorded percentage of respondents was 56.4% who used simple pit latrine with a slab. The other remaining technologies were cistern flush toilet 2.1%, pour/manual flush toilet 19.8%, VIP latrine 11.1%, pit latrine with slab and pit latrine without slab 10.7%. There was no current existing data on Kombolcha town toilet technology type basis except the 2007 CSA housing units and their respective types of toilet facility census result, that showed of all Kombolcha town 15,261 housing units 3505 (23%) have no toilet facility whereas 861(5.6%) have shared or private flush toilets,1760 (11.6%) VIP latrines, and 9129 (59.8%) of housing units have pit latrine technologies.

The present finding or result is far lower than the previous CSA result in HHs with no toilet facility and HHs having flush toilets. Whereas the study results in line with CSA results in a number of HHs having VIP latrine which is 11.1% and 11.6% respectively.

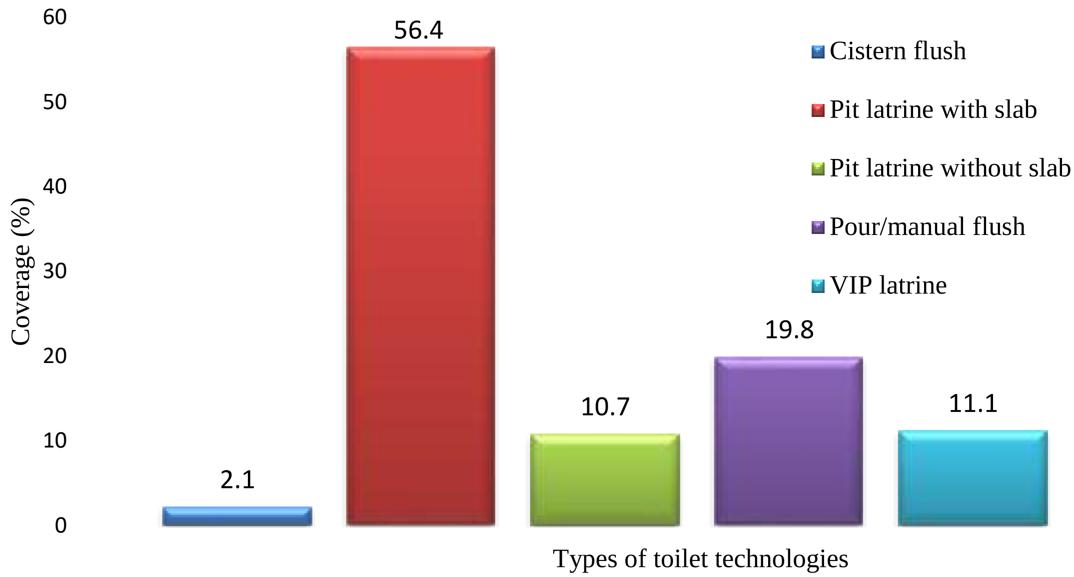


Figure 11: Toilet technologies or user interfaces (%)

As shown in Figure 11, 89.3% (all toilet facilities except pit latrine without slab according to JMP definition) of households informed/observed using an improved facility, where 17.3% of households used a private facility and 72% of households a shared toilet (HH survey). Of the 10.7% of households reporting the use of an unimproved facility in the figure above (pit latrine without slab), 7% of these are reported as private facilities, while 3.4% are reported as shared facilities.

According to WHO and UNICEF, (2017) Sustainable Development Goal (SDG), improved sanitation facilities categorized as safely managed, basic and limited facilities. Improved facilities that are not shared count as either basic or safely managed services. Thus 17.3% (private toilet except for pit without slab) is basic and 72% limited facility (shared toilet between HHs). The remained 10.7% categorized as unimproved facilities (Table 3).

Table 3: Sanitation facility used, by JMP category

Type of facilities	Categories	Percentage
Improved facilities	Basic (facilities that are not shared with other households) facilities	**17.3%**
	Limited (shared between two or more households) facilities	**72%**
Unimproved facilities	Use of pit latrines without a slab	**10.7%**

In this study, the overall improved sanitation facility coverages, as shown in Table 3, are 89.3% and 10.7%, of which is unimproved facilities are somewhat closely similar to the Kombolcha town health office sanitation department report, (2019) which is improved facilities 91% and unimproved facilities 9%.

However, the study result revealed or differ from the study result of JMP (WHO and UNICEF, 2017) which reported the urban sanitation coverage in Ethiopia for basic, limited (shared), unimproved sanitation facilities and open defecation practices as 18%, 30%, 44%, and 7% respectively. As JMP result above the improved sanitation facilities remains 48% (for basic and limited facilities) which highly differ from the current study 89.3%. This much different result could be due to the JMP country-level urban sanitation coverage estimation rather than each individual towns and cities. The open defecation practice result of the study discussed below in this session.

I. Pit latrine technologies

As the study has shown, pit latrines are dominant types of toilet technologies in the town (67.1%). Low and middle-income households built those types of technologies for permanent or temporary use (KII9). As per the held observation of toilet technologies during the household survey, different types of pit latrines were in use in Kombolcha town i.e. pit latrine with slab and latrine without slab/traditional latrines as shown in Figure 11.

Traditional latrines or pit latrine without slab: They are commonly found in homesteads particularly those in the periphery areas of the town (clusters 2 and 9). The traditional latrine's superstructure was made of plastics, cloth rags, and plastics as a roofing material (HH observation during an interview) or no roof at all as illustrated in Figure 12A. This type of Pit latrines collects FS with totally unlined walls and bottom then after abandoned when full and covered with soil. The held observation during HHs identified this type of toilet facility invite flies and also retain odor in the room.

Simple pit latrine: It is the most dominant type of toilet technology (56.4%) in Kombolcha town as Figure 11 illustrates. The held interview with pit/septic tank installers or masons shows numerous types of superstructures are realized in the municipality depending on the income of the users to construct this type of toilet. The more permanent structures are made of wood, brick, and cement while temporary ones are made of plastics, cloth rags and plastics with metal or plastic sheet roofing material (the held observation during the household survey) and (KII9). The wood slab which is just cemented at slab level to provide a smoother finish is the most common slab type provided to pit latrines (Figure 12B).

However, the lining of the pits is not a very communal practice. Mostly, pit latrines with slab constructed with old rubber truck tires that used to produce partially lined and stable walls in case of the existence of groundwater (KII2 &KII9). Infiltration of the liquid into groundwater and overflows during the rainy season those toilet technologies have made pit latrines major causes of groundwater pollution. Pit latrine with slab also collects the sludge from the user interface into unlined/partially lined walls with masonry and open bottom on some occasions (KII9).

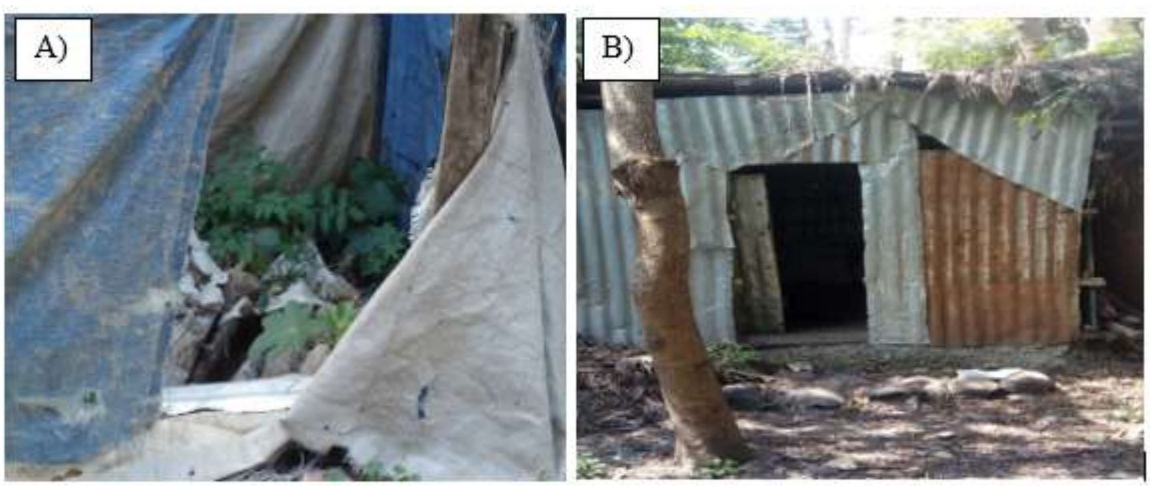


Figure 12: Traditional pit latrine, & B) Simple pit latrines (pit with slab)

The study results showed that more effort must be put into place to wipe out the existence of pit latrines in areas where high groundwater exists (cluster 3,5 and 7 of the study area).

The use of these latrines is against the national hygiene and sanitation directive of the Amhara region, 2008 which requires toilet technologies that should construct by considering the groundwater source and not greater than 3m depth and also describes the facilities should be kept clean and hygienic. The study result determines the most operation and maintenance practices of pit latrines revealed the key principle of safe toilet management, design, construction and use via separate households from excreta, avoiding both active contacts and passive contact (WHO, 2018) which discussed in health risk exposure session 4.3.

II. Ventilated Improved Pit latrines (VIP)

As the Key informant interview (KII9) results show, most people do not understand the difference between VIP latrine and simple pit latrine that's why only 11.1% of VIP latrine technologies found Kombolcha town. In most cases, households constructed VIP latrines for a permanent basis tighten with their house (KII2, KII9). Households build a ventilated improved pit latrine to reduce fly and odor nuisance via means of ventilation.

However, construction did not make them function as VIP rather than installing just only vent pipes in the HHs level. But most VIP latrines are found in institutions, (Appendix 4, Figure 4.2) and areas where shared toilet user households live in (KII9 & field observation), that's why NGOs or the municipality built these VIP toilets for those who had low income and kebele or kuteba houses (Observation and KII9). Likewise, the household survey results show fewer VIP latrine users (11.1%) in figure 13 above when compared with other sanitation technologies. The study identified that the household-owned VIP latrines operated and managed in a similar way with that of pit latrines and pose a similar problem.

III.Septic tanks

Flush toilets (cistern and pour-flush user interfaces) are found in high-income households, hotels, and recreational centers. All flush toilets are connected to lined tanks with impermeable/semi-permeable walls and an open bottom, locally referred to as septic tanks (KII9). These septic tanks were comparatively better managed (in terms of preventing Odour and fly nuisance) than other toilet technologies. The key informant's estimation of septic tanks with different containment systems discussed in detail in the containment session 4.2.2.

The household survey result and key informant's estimation indicated the most septic tanks technologies in Kombolcha town are septic tanks lined with semi-permeable walls and open bottom. The condominium houses in the Kombolcha town were mostly constructed with septic tanks lined with semi-permeable walls and open bottom so as to infiltrate the incoming liquid into the surrounding soil with no outlet or soak-pit for effluent treatment (KII4, KII9). As the population in condominium houses gets high, the generation rate of liquid waste is greater than the rate of infiltration of the soil at the bottom of cesspool which resulting in the frequent filling of the cesspools which need frequent desludging/emptying. Consequently, it results in an overflow and illegal disposal into drainage canals due to the waiting time of emptying services (KII4).

The study result identified 11.8% of septic tanks with impermeable/semi-permeable walls connect their outlet into open drain/water body (Table 6) and the remaining 5.7% septic tank's containment failed, damaged, collapsed or flooded. Thus, the study result determines 17.5% of septic tank users are against the Amhara regional state health department hygiene and sanitation directive, 2008 that dictates the above situations as against bye-laws. In addition, those septic tank management practices were also revealed the WHO guidelines on sanitation and health, 2018 that determines any containment technology (septic tank, fully lined tank, pit latrine, open-bottomed tank, etc.) that has an effluent outlet discharging to an open drain, a water body or to open ground as a source of sever exposure of health hazardous events.

IV.No toilet facility/open defecation practice

Open defection is encountered commonly in the Kombolcha town. It has been credited mainly to the homeless who have no sanitation facilities (KII6). Evidence of open defection was observed around public toilets, roadsides, riversides, markets, and open drains as shown in Figure 13.

Discussion with community members together with observations during field survey recognized open defecation as practiced in almost all parts of kebeles especially old kebeles (kebele 3 and 2): either by newcomers from remote areas for work opportunity and market exchange purpose, "a few" mainly children, or elderly people and in some occasions by households with having overflowing latrines during rainy seasons (FGD, KII6).

Open defecation practice is deteriorating especially in the Borkena river that passes near to the central market which so many people come together from remote and rural areas for exchange who familiar with open defecation. During the field survey or transect walk in different parts of the town including low-income areas, in two kebeles (3&5) people, defecate near to the public toilet around kebele 5 football field and kebele 3 Borchele market as well as roadsides (flying toilets). As the health extension workers reported, the municipality Byelaws permitted to punish or charge 20 to 50 ETB for those who openly defecate but in recent years those who openly defecate in open fields did not allow or refused to be punished.

Even though the current open defecation practice worsens and increasing over time (KII6), the extent to which it is currently practicing in Kombolcha has not been expected to determine due to lack of census data or a reasonable estimated number of people who practice open defecation. For the tenacities of this study, it is considered to be 7% which was estimated by WHO and UNICEF, (2017) as a country level for Ethiopian urban areas.

Figure 13: Open defecation practices in Kombolcha town

The study finding was against the Municipality's sanitation bye-laws which forbid any person to not openly defecate around public toilets, roadsides, riversides, markets, and open drains, etc. and also the study result was in contrary with the SDG goal 6.2 (WHO and UNICEF, 2017) end open defecation by 2030.

4.1.3 Communal and Public toilets

A. Communal toilets

According to the Kombolcha town health office sanitation department report, (2019), there were 89 communal toilets in Kombolcha town. However, FGD and the held KII with health extension workers interview showed, kebele rental house communal toilet users in slum areas (Borchele) share one seat for 25-30 households whereas kuteba house households share one seat for three households. As the held transect walk in vulnerable areas and observation during HHs survey showed, difficulties infrequent cleaning and desludging of the facility and poor maintenance practices related to the dense population settlements that make the management difficult.

In addition, land tenure and/or land availability for the construction of individual household toilets worsen the situation. During the transect walk, some of the communal toilets were full and waiting for emptying, and leakage from other communal toilets was seen. The leakage from those technologies passes through access roads between living houses that children can access to play over it. Consequently, most communal toilets were the source of health risk exposure events for users rather than give them a service (Appendix 4, Figure 4.11b).

Generally, the study identified communal toilets especially in slum areas of kebele house dwellers, the facilities were in contrast to the guideline for communal toilets requirements by WHO, (2018) which states the toilet should provide each member of the households to have equal and ready access to the facility and that the toilet should be kept clean. And also All shared or communal toilets should have:

- Handwashing facilities with a water supply and soap; and
- Menstrual hygiene management facilities;
- Separate cubicles for men and women, or gender-neutral cubicles
- Suitable modifications for all users e.g. access for people with disabilities

B. Public toilets

Currently, there are 7 public toilets in Kombolcha town which always or partly open most of the time from 7 a.m. to 6 p.m. During the field survey, it was carefully distinguished that the PTs were not clean and sustained except PT at the central market with flush water usage. These PTs were not equipped with facilities for males and females. Among these 7 PTs, 3 have a bathroom with a shower and it charges 3ETB for use. But only one public toilet at the central market gives a shower service; the remaining two public toilet showers were malfunctioning. The municipality owns the toilets and gives permission to a private company or disabilities to run them. They charge 2 ETB for toilet use (water or toilet tissue is also provided for anal cleansing) and 0.5 ETB for urinating use.

Typically, around 25 to 30 people use these public toilets per day (KII10). As the attendants reported the public toilet located at the central market and connected to a fully lined (sealed) tank, which is emptied 3 to 4 times per month due to added greywater from 6 shower taps. A list of the public toilets in the municipality is shown in Table 4.

Table 4: Summary of public toilets in Kombolcha town

Location		**Type**	**Size**	**Payment (ETB)**	**Comments**
Central market	1	Flush toilet	16 stances	2	Always open and attendants based
	2	Basic pit latrine	12 stances		
Borchele Market		VIP	6 stances	2	Always open and attendants based
Kebele 5 sport field		VIP	4 stances	2	Caretaker available and not always open
Kebele 4 sport field		VIP	4 stances	2	Caretaker available and not always
Old bus station		VIP	N/a	N/a	N/a (on rehabilitation)
New bus station		Basic pit latrine	4 stances	2	Always open and attendants based

Figure 14: A) Different public toilet facilities and B) their user interfaces

The study recognized that public toilet maintenance was a potentially more challenging task especially in busy locations (central market PTs), where the high use and diffused responsibility means that more frequent cleaning is required to maintain each toilet. As shown in Figure 14, frequent filling of tanks and pits together with long waiting time to get emptying service results in a health risk exposure. The study also identified open defecation practices around the public toilets due to lack of regular opening and willingness to pay for service fees; even though the charge fees are affordable (Figure 13C).

4.1.4 Categories of fecal sludge origin

Fecal sludge is generated from various sources (Community/Public toilets, institutions, commercial and industries establishments) in addition to residential sources, though for the production of this SFD, only the residential sources were considered Since there was a lack of data on the excreta generated from those various sources and contribution from these sources is not certain.

I. Institutional and Public toilets

This section included existing sanitation facilities mainly from academics and health centers and public toilets. Currently, there are 23 kindergartens, 32 general primaries, 3 secondary and preparatory, 4 higher education institutions (colleges) and 1 university

(KIOT) with so many students who come from both within the city and outside the boundaries of the municipality in pursuit of a good education. (Kombolcha town Education Office,2019). The whole schools in the municipality use non-water born (pit and VIP latrines) toilet facilities except a few higher education institutions. The latrines whether in private or public schools have to be built according to specifications from the Ministry of Education (KII9, 2019).

The Kombolcha town has 9 medium clinics, 15 junior/polyclinics, 4 health centers and 6 developing health posts to maintain the health of the community so as to make them healthy and more productive.

II. Commercial and Industrial establishments

The municipality has 209 smalls to large scale industrial establishments, 16 hotel and truism investments (Kombolcha town administration, 2019). In addition, the city has two markets for daily exchange. There was a lack of data on toilet facilities within different industrial establishments. The toilets facilities in most hotels in the city are connected to the septic tank (KII2, 2019). Whereas, in market places, visitors are dependent on public toilets as discussed on the above public toilet session (Figure 16).

4.1.5 Evacuation and transportation of fecal sludge

Habitually fecal sludge from pit latrines, VIPs and lined tanks with impermeable walls and open bottom (locally referred to as septic tanks) are emptied when the containment gets full. Motorized emptying is the foremost choice used to empty the pit latrines or the septic tanks (lined tanks with impermeable walls and open bottom) (KII2). (Appendix 4 Figure 4.4 a and b)

The municipality has one vacuum truck and the Wollo University has also one vacuum truck (only providing service for the University itself). The municipality does not provide sufficient emptying services with one vacuumed truck (8 m^3) nor are there any private trucks in the town to give an emptying service. Instead, private vacuumed trucks come from Dessie town (located about 23 km away) on request with a volume ranging from $6m^3$ to 10 m^3. (KII 1, KII2). Currently, there are 6 private vacuumed truck that gives emptying services for Kombolcha town as well as for Dessie town (KII 1). As the Kombolcha town water supply and sewerage authority department supervisor reported, the private and

Dessie municipality vacuumed trucks are hauling sludge from Dessie town into Kombolcha town fecal sludge treatment plant with only 200 Birr fees to unload at the plant; since Dessie, FSTP is not currently functional. The interview with the Kombolcha municipal vacuumed truck driver result showed that its average daily frequency of emptying is 5 trips for five and a half days per week (14014 m^3 per year)

According to emptying service providers, interview and household survey results showed, it costs approximately 500 ETB per trip to engage the emptying services with the municipality vacuum trucks, whereas private emptying service providers vary from 1200 to 2200 ETB (due to transportation cost as they come from Dessie town). The private company vacuumed truck operators pay 200 Birr per truck to unload/discharge at the fecal sludge treatment plant (KII2 & KII8).

About 63% of household respondents reported as their toilet have never been emptied/never got full including abandoned pits with soil cover when it got full. Illegal emptying practices, which were not reported by the HHS but the situation was due to tanks containing outlet pipes that discharge contents out of the tank and reduction of accumulation rates according to emptying service providers interview result. On the other hand, systems in areas with high groundwater tables (cluster 3,5 &7) may require emptying services two to three times per year as the household survey result (KII2).

Among the sample households asked if their toilet has ever overflowed, 5.8% responded to the occasions of pit overflow due to lack of emptying service when needed. Whereas 11.9% of households reported as their toilet overflowed before due to rising groundwater table in the rainy season (Figure 15). On the other hand, among households those experienced with emptying practice 51% reported their pit/ tank emptying frequency was less than one year.

As shown in Figure 15, 12.2% of the household's emptying frequency was 4 and above years (8.9% in 4 to 6 years and 3.3% above 6 years). The emptying frequency pit latrines depend on variation in sludge accumulation rates. Shared pit latrines between the house owner and rental classroom households were emptied more frequently compared to private pit latrines because they are used by a large number of people, who also use them as solid waste disposal sites (KII 2).

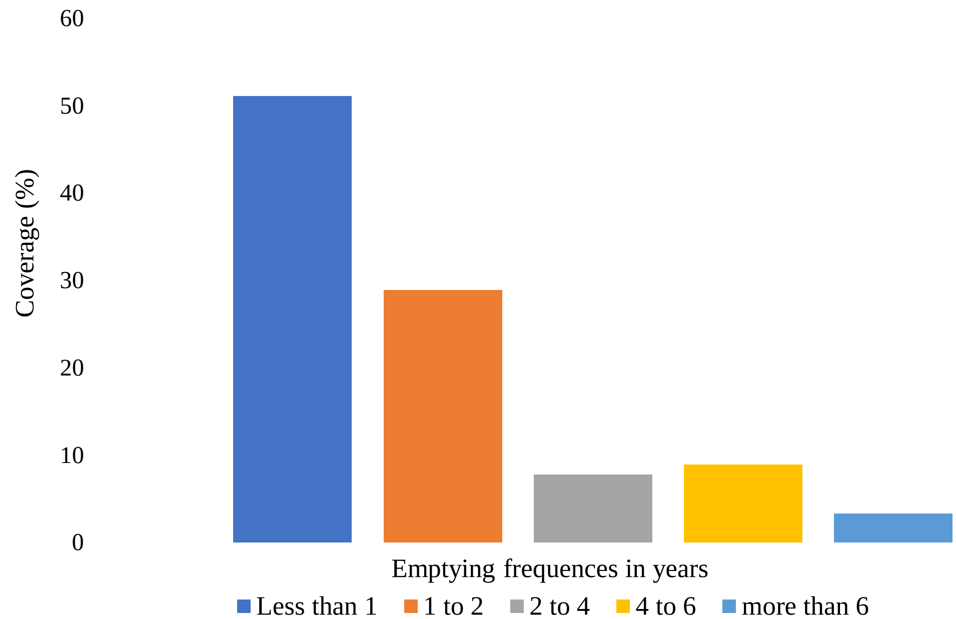


Figure 15: Percentage frequency of emptying pits/tanks

4.1.6 Fecal sludge Treatment and disposal/end-use practices

Background and location

There was no liquid waste treatment plant before 2008 for the municipality. However, the FSTP constructed in 2008 with Entricklungs Bank of Germany and Kombolcha town administration with the assistance of the Ministry of Works and Urban Development co-financed budget. Presently, the plant is receiving fecal sludge from Kombolcha town, Dessie and other neighboring towns (KTWSSA, 2019).

The plant located in the lowland area near the town and about 3.5km away from the town center and uphill of the Borkena river about 50-70m away under Water supply and Sewerage Enterprise office supervision.

A) Treatment

The FS treatment system has four main components: unplanted drying beds, maturation ponds, storage lagoons, and sanitary landfills. There are three drying beds which have different sizes, one of the three drying bed has 6 cells with a dimension of 10x28 m each. Whereas the remaining two drying beds have 8 cells each with the same dimension of 280m^2 (Appendix 4, Figure 4.9). As per the held interview with the plant supervisor, the storage lagoons constructed purposefully for rainy season fecal sludge storage to not use drying beds as the moisture content of the sludge increases and the drying period is prolonged (Appendix 4, Figure 4.6). But some vacuumed trucks were unloading the fecal sludge into drying beds when observations made during the wet season (August 2019).

The FS treatment process comprises of dewatering of the fecal sludge by the percolation of liquid through the sand beds (unplanted drying beds) and evaporation. The filtered liquid through the drying bed goes to 2 maturation ponds for further biological treatment processes (pathogen or fecal bacterial removal with HRT and high temperature or high radiation of the sunlight leading to solar disinfection) (Appendix 4 Figure 4.7). But during the site visit, it was seen that the destination of final effluent leaves the maturation ponds was not yet defined. The cake/dried sludge is removed from the drying beds when it gets very dried up into sanitary landfill site at the beginning of the plant operation in 2008 and extends for two or three years only (KII 1 & KII 2). Unlike, the removal of dried sludge from the drying beds was not yet to be done as of the 5 times of visiting the site (from March to November 2019).

According to KTWSSA FSTP recorded report, from 2016 up to 2019 with a total of 1819, 2546 and 3086 tankers of fecal sludge with an average volume 7m^3 (12,733 17,822 & 21,602) m^3 have been dislodged from Kombolcha town and other neighboring towns (Appendix 3 Table 12).

Operation and Maintenance aspects of the plant

KCWSSA has a branch office located near to the liquid FSTP. Operations at the disposal site were controlled by those branch office workers (KII8, 2019). There was also a security person at the site who controls in and out, and all activities within the site area. According to the plant security persons or attendants, no maintenance works have been done at the plant even if there were a need for maintenance in parts of the plant such as inlet screening and fractured masonry walls of cells as shown in Figure 16.

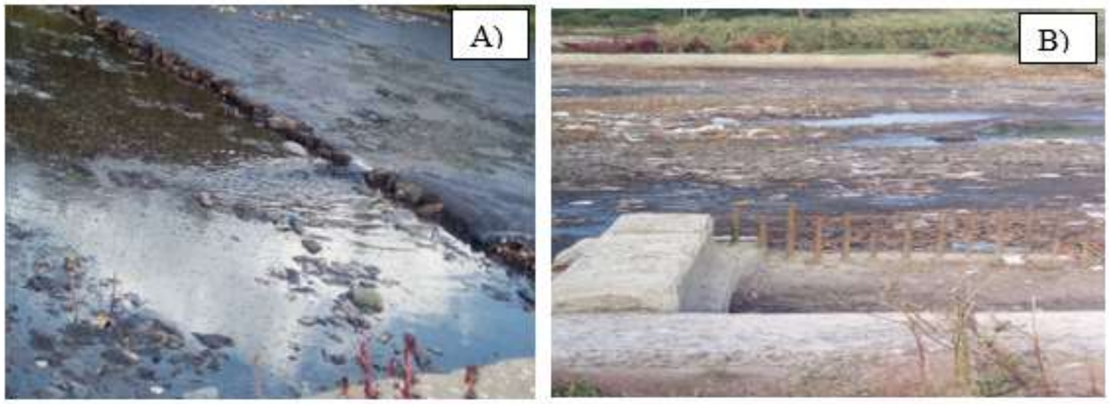


Figure 16: A) Drying bed cell's fractured common walls and B) accumulation of rubble and trash

B) End-use/Resource recovery options

Interviews held with the head of sewerage service and FSTP attendant showed that currently, there are no activities for the production of end products from fecal sludge. This situation was also triangulated with an observation of the plant and there were no end-use activities. The former Kombolcha town sanitation and beautification department officer reported that there were resource recovery practices from dried sludge on unplanted drying beds as end products for soil amendments in horticulture (gardening). But this practice was continued for only one or two years from the beginning of plant operation in 2008 (Appendix 4, Figure 4.8).

4.2 SFD Matrix Formation

4.2.1 Groundwater contamination risk estimation

Due to the lack of available groundwater maps or recorded statistics concerning the actual groundwater levels of the town, the estimations were made based on, HH survey, literature review and key informant interviews (KII9). The risk of groundwater pollution was calculated using the SFD Graphic Generator Groundwater Assessment Helper Tool. The Helper tool methodology and input data required have been discussed in the data analysis session 3.4.3. In addition, the soil type of the town for identified clusters also described in figure 10 above and used as an input for the groundwater contamination risk estimation.

After all the calculation was made for some parts of the town were groundwater sources existed within the private properties. The identified vicinities with groundwater sources were found at the center of town in lowland areas (cluster 3,5&7) and periphery areas (cluster 9). As the HHs survey result showed, households who found at the center of town in lowland areas had groundwater sources in their property but their main source of drinking water was piped water from the municipality. Instead, those households used their groundwater source for washing clothes, flushing toilets, and washing housewares rather than used as drinking water sources (observation during HH survey and KII6). The average groundwater depth was found less than 5m (HH survey and observation during the survey) in these areas and the identified groundwater technologies were protected hand-dug wells.

Generally, among the 243 sampled HHs 3.7% of them (who found in the specified cluster) own groundwater sources for multi-purposed except for drinking as the tap water is available from the municipality. Consequently, the Groundwater Assessment Helper Tool showed a low risk of groundwater pollution. (Appendix 3, Table 15)

Whereas most of the households found in the hilly area (cluster 9), used unprotected spring as their main source of drinking water according to the HH survey result. As the HH survey result showed 3.2% of households relied on spring water sources. Likewise, the toilet technologies in this area were found unlined pit latrines abandoned when full and mostly traditional latrines. In addition, those latrine technologies lay in the upstream side of the unprotected spring which is the main source of drinking water approximately 100-200m distance away from the most household toilet facilities. As a result, the Groundwater pollution Assessment Helper Tool showed significant groundwater pollution risks (Appendix 3, Table 15). Which means 3.2% of the population lives areas with a significant risk of groundwater pollution.

4.2.2 SFD Matrix explanation

A. Containment

The onsite sanitation is divided into two categories. A containment system in which FS is contained and one in which FS is not contained. FS is considered not contained when the FS infiltrates into the ground and pollutes the high groundwater table or if the supernatant or FS from the septic tank flows through open-drain/water body/open ground. Whereas the FS was considered when the sanitation technology and/or system which ensures a safe level of protection from excreta. As the household survey and observation made during the survey identifies the Kombolcha town population was 100% dependent on onsite sanitation (pit latrine or septic tank) technologies.

The percentage of containment technologies in Figure 17 was determined from household survey result. All listed containments in this Figure 17 were also determined from 100% toilet facility user households, unlike households without toilet and faced to open defecation was not yet reported or observed during HHs survey. However, following the wide range of open defecation practices in all parts of Kombolcha town as discussed in the above 4.1.2 on-site sanitation technologies, open defecation session, the containment types results was readjusted or taken from 93% and the remaining 7% was taken as open defecation practice based on WHO and UNICEF, (2017) a country level Ethiopian urban areas open defecation estimation.

The other containment technologies (15.5%) in Figure 15, included the containment technologies for both pit latrine and septic tank facilities i.e. Pit latrines abandoned when full and covered within a significant GW risk area, Containment failed/damaged, collapsed or flooded and lined pit with impermeable walls and open bottom.

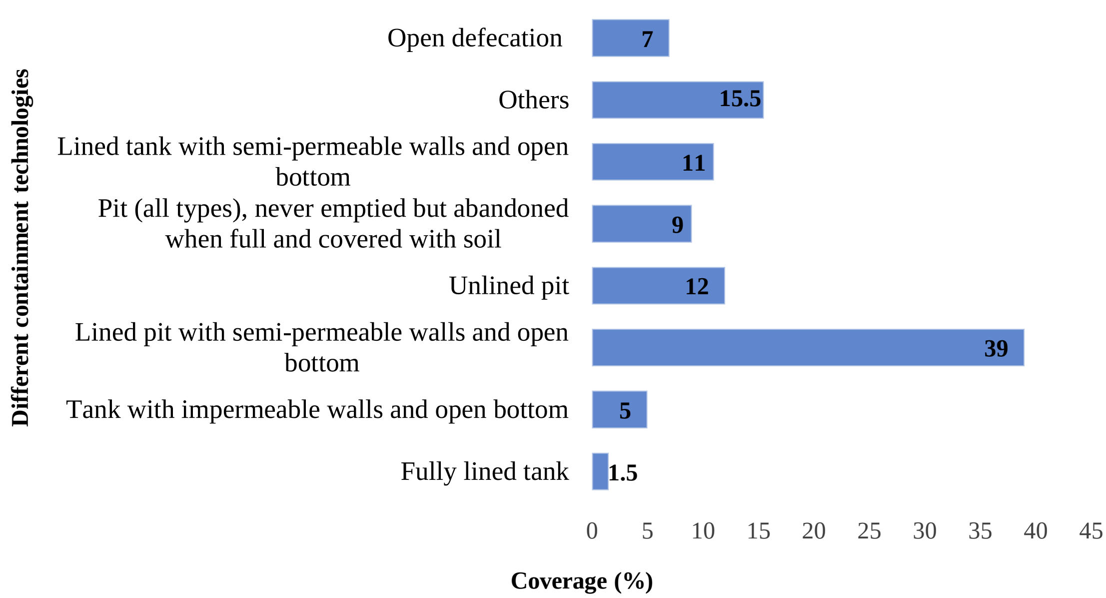


Figure 17: Containment types in percentage

Table 5 represents the overall containment technology estimations based on the household survey results, key informant interviews, and focus group discussions. As the study result is shown in Table 5, almost (71.8%) three- fourth percent of Kombolcha town inhabitants use pit latrine technologies including VIP latrine. Whereas, tank (locally referred to as septic tank) users were much less (21.2%) when compared with pit latrine users. The study result also finds out uncontained on-site sanitation technologies (16.5%) which FS infiltrates into the ground and pollutes the groundwater or FS from those technologies flow through open-drain/water body/open ground and cause for serious health and environmental hazards. Although, 76.5% of FS from pit latrine and the septic tank was contained on-site. For FS contained/not contained emptiable or not emptiable has been discussed and tabulated in the emptying session of Table 5.

Table 5: General on-site sanitation technologies and containment estimations in (%)

Septic tank	In practice Cesspool/tank	**21.2**	
Pit latrine	All type of latrines including VIP	**71.8**	
Open defecation	Defecation practices at open ground, drainage canals, etc.	**7**	
FS contained	FS contained, not emptiable	8	**76.5**
	FS contained, emptiable	68.5	
FS not contained	FS not contained, emptiable	9.5	**16.5**
	FS not contained, not emptiable	7	

Regarding the general containment estimations made in the above Table 5, different source estimations were gathered through which taking into account the official survey reports underestimation and the HHs intolerance to admit their illegal practices. Thus, more weight was given to interview statements especially for illegal toilet outlet connections and related issues. Analysis of the interview statements, FGD, household survey, and visual inspection during the HHs survey result leads to the following quantitative estimations for septic tank and pit latrine technologies and their respective containment systems.

Septic tank containment system estimations:

The key informant interview with Kombolcha town health department sanitation officer and health extension workers showed the existence of septic tanks with letting fecal sludge discharged to open drain/water bodies as the facility got full or during the rainy season. In addition, their interview also indicated as there were complaints from some households due to foul smell and interruption resulted from neighborhood's illegal septic tanks outlet connections. Generally, the interview result from those key informants was 1% or 2% including septic tanks from condominium houses. The FGD showed that out of 100 households 5 to 10 households having septic tanks discharge into an open drain by using the pump during the rainy seasons as the facility got full due to raised groundwater.

As pit/septic tank installers or masons interview indicated on average more than 95% of septic tanks (practically cesspool/tanks) are neither fully lined nor fully watertight. The remaining 3-5% fully lined tanks are not even watertight and mostly constructed to organizations or high incomed households who found in high groundwater table areas (kebele 2,3&5). In addition, the masons also reported that more than 75% of septic tanks are lined with semi-permeable walls (dry masonry with only hardcore) and open bottom so as to infiltrate the incoming liquid from the user interface. About 15 to 20% of septic tanks are lined with impermeable walls and open bottom and built by inhabitants who live in areas with high groundwater tables so as to protect their tank from collapse. Those estimation results were somehow in line with the household survey result; thus, the household survey result was directly taken as shown in Table 6.

Apart from the above estimations, 1.2% of septic tanks from overall containment technologies that got flooded due to the raised groundwater table and lack of proper emptying service was determined through visual inspections during the HH survey. Generally, Table 6 below represents, the resulting final estimations for the septic tank (practically fully or partially sealed tank) based on the HH survey, FGD, visual inspections, and key informant interviews.

Table 6: Estimations on Cesspool/tank (locally referred to as septic tank) systems

No	Tank/cesspool technologies	Types of tank technologies in (%)	Of overall (93%) containments in (%)
1	Fully lined tank (sealed but not watertight), no outlet or overflow	7	1.5
2	lined tank with impermeable walls and open bottom, no outlet or overflow	23.6	5
3	lined tank with impermeable/semi-permeable walls to open ground/open-drain/water body	11.8	2.5 (KII, FDG)
4	Lined tank with semi-permeable walls and open bottom, no outlet or overflow	51.9	11
5	Containment failed, damaged, collapsed or flooded - no overflow (flooded)	5.7	1.2
Total percentage of technologies		**100**	**21.2**

Pit latrine containment system estimations:

Similarly, on septic tank containment system estimations, various key informants were also estimated on pit latrine containment technologies. As the masons and households reported, kombucha inhabitants who use unlined pit latrines in areas with a high groundwater table (kebele 2&5), construct their pits with rubber old truck tire to make the walls of the pit stable as well as emptiable. However, unlined pits were mostly reported to be built in low water table areas in order to safeguard their pit from collapse.

The pit containment type estimation was primarily on HH survey result. However, some judgments and adjustments were needed and made reasonably on quantitative data from HHs survey where believed that the data has biased information by households related to fear from to not be charged for their illegal practice (e.g. illegal toilet outlet connections). Thus, pit latrines permeable/semi-permeable walls letting FS discharge to open drain/water body with pipes or bowl was estimated (7%) based on KII4 & KII6 (up to 5%) & FGD (10 to 15%) estimations for the accuracy and reliability of data. The remaining pit containment technology estimations were from household survey results and visual inspections. Generally, the following pit latrine containment systems in Table 7 were differentiated and estimations based on various sources. The containment technologies percentage value in Figure 17 was readjusted by adding unspecified containment types during HH survey i.e. 7% pit latrine discharging FS into open drain/water body in Table 7, and 2.5% for septic tank containment in Table 6.

Table 7: Pit latrine technologies in Kombolcha town

No	Latrine technologies and its respective containments	Pit latrine technologies (in %)	Of overall (93%) containments (%)
1	Lined Pit with semi-permeable walls and open bottom, no outlet or overflow	48.7	35
2	Lined Pit with impermeable walls and open bottom, no outlet or overflow	7	5
3	Lined pits with Impermeable/ semi-permeable walls and open bottom, letting FS discharge to open drain/water body with pipes or bowl	9.8	7 (KII and FGD estimation)

4	Unlined pit with no outlet or overflow	15.3	11
5	Pit latrines abandoned when full and covered with soil, no outlet or overflow in significant GW risk areas	4.5	3.2
6	Pit latrines abandoned when full and covered with soil, no outlet or overflow	11.1	8
7	Containment failed, damaged/collapsed/flooded - no overflow (pit flooded)	3.6	2.6
Total percentage of technologies		**100**	**71.8**

SFD matrix containment input calculations

After all, the estimated containment technologies for both pit latrine and septic tank systems in Table 6 and Table 7 became an input to develop SFD. However, the estimations were challenging, as a lot of different systems exist in the town that differs from SFD system terminology for both tanks and pits. As a result, there was a need for group similar technologies into SFD system terminology categories (for both tank and pit latrine systems). Thus, tanks and pits with the same terminology were merged.

Finally, the estimations on the onsite sanitation containment systems were presented as follows in Table 8. The final estimations for the SFD matrix containment with own variable and SFD reference variables found in Appendix 4, Table 16.

Table 8: Final estimations for the SFD matrix containment calculations

№	Containment technologies	Estimations (%)
1	Fully lined tank, no outlet or overflow	**1.5**
2	lined tank with impermeable walls and open bottom, no outlet	**10**
3	Lined/partially lined tank discharged to open drain/water body	**9.5**
4	Lined pit/tank with semi-permeable walls and open bottom, no outlet	**46**
5	Unlined pit with no outlet or overflow	**11**
6	Pit latrines abandoned when full and covered with soil, no outlet	**8**
7	Pit latrines abandoned when full and covered with soil, no outlet or overflow in significant GW risk areas	**3.2**
8	Containment failed, damaged, collapsed or flooded - no overflow	**3.8**
9	Open defecation	**7**

B. FS emptying, transportation, and treatment

Emptying: The fecal sludge emptying analysis was formed based on the values of variables F2(e), F2(n), F10(e) or F10(n), and containment technologies that have never been emptied which gathered through a household survey.

Thus, F2(e), F2(n), F10(e) or F10(n) was created to differentiate between systems that can be emptied versus those that cannot, leads to the following possible containment variables:

- ☞ F2(e) = FS contained, emptying possible
- ☞ F10(e) = FS not contained, emptying possible
- ☞ F2(n) = FS contained, emptying not applicable
- ☞ F10(n) = FS not contained, emptying not applicable.

The main challenge in estimating the different onsite sanitation emptying situation was unknown contributions from containment technologies which found as emptiable but they have never been emptied before. However, it was assumed that FS in the stream F(2e+10e) but remains unemptied to include the FS from pits or tanks which have never been emptied due to illegal emptying practices.

As the household survey result indicated, 37% of households were experienced in a pit/tank filling up and emptied their facility to reused again. The remaining 63% pits or tanks were determined as emptiable contained/not contained facilities that have never been emptied before and emptiable technologies with illegal outlet connections. However, 78% of onsite technologies were contained/not contained and emptiable (except open defecation, damaged/collapse, and fully abandoned pits) as shown in Table 8. Out of 78% of emptiable toilet facilities, 41% (78%-37%) was emptiable but not emptied. Out of 41% emptiable but unemptied technologies, 9.5% was not contained and emptiable but unemptied instead discharged to open drain/water body. The remain 31.5% is contained and emptiable but not yet emptied technologies.

Table 9: Emptying variables and their Description

Description	Kombolcha context	Percentage value
FS contained not emptied	=F2(n) + F2(e) not emptied	8+31.5=**39.5**
FS contained, emptied	=F2(e) emptied	**37**
FS not contained, emptied	=F10(e) emptied	0
FS not contained, not emptied	=F10(n)+F10(e) not emptied	(3.2+3.8) + 9.5 =**16.5**

Generally, Table 9 presented the FS contained/ not contained that has been emptied or not yet emptied technologies.

Transport: There was limited evidence of vacuumed trucks dumping FS to land or parts of the town environment before reaching the treatment plant and fecal sludge being removed informally by households themselves. In addition, it's observed that the FSTP was located near to the town (3 to 3.5km from the center of the town) and its access road was suitable for haulage of FS during rainy seasons. Similarly, the municipality has a restricted measure for those discharge the FS into the environment instead of FSTP (KII2, KII8 & KII7). Thus, by taking into consideration the above enabling situations, the whole FS removed from pits and tanks (evacuated using both municipal and private vacuumed trucks) was considered as delivered to the fecal sludge drying beds (FSTP) but 90% was considered rather than taking 100% the perfect figure.

Treatment: The key informant interview and the held observation identified poor operation and maintenance issues of FSTP that discussed in session 4.2.4. Similarly, the efficiency of treatment (FSTP) at the fecal sludge drying beds was unidentified and goes unrecorded and also the plant is not operating optimally. Thus, a figure of 50% treatment efficiency was used to produce SFD. This estimation was drawn based on SFD-PI, (2017) methodology for unknown data on the efficiency of the plant and limited evidence on FSTP operation together with self-judgments after repeated field visits as well as referring previous SFD preparations (Furlong et al., 2016, Scott et al., 2016)

Table 10: Estimations on FS emptying of on-site sanitation systems/technologies

System	% of all containments	How many emptied (HH survey)		How much delivered to FSTP	
Fully lined tank, no outlet	1.5	100%	1.5%	90%	1.3%
lined tank with impermeable walls and open bottom, no outlet	10	68.6%	6.86%	90%	6.2%
Lined pit/tank with semi-permeable walls and open bottom, no outlet or overflow	46	57%	25.9%	90%	23.4%
Unlined pit with no outlet	11	25%	2.75%	90%	2.5%
Total emptied FS			**37.1%**		**33.4%**

Table 10 presents the overall FS emptying of on-site sanitation technologies. The percentage of containment technologies in table 10 was estimated in Table 8. Whereas, the percentage values of emptying for each containment technologies were determined from containment types and their respective emptying practices which gathered through a household survey. In addition, from the FS transport session above, it has been estimated that 90% of emptied FS from on-site sanitation technologies as delivered into the treatment plant; thus, it is presented in Table 10 for emptying estimations.

Generally, the estimated various containment technologies in Table 8 and their emptying practice from household level up to fecal sludge treatment plant delivery in Table 10 as well as 50% treatment efficiency together with the percentage of the population using each on-site sanitation systems were used to develop the shit flow diagram (SFD) as shown in Figure 18.

4.2.3 Excreta Flow Diagram Presentation

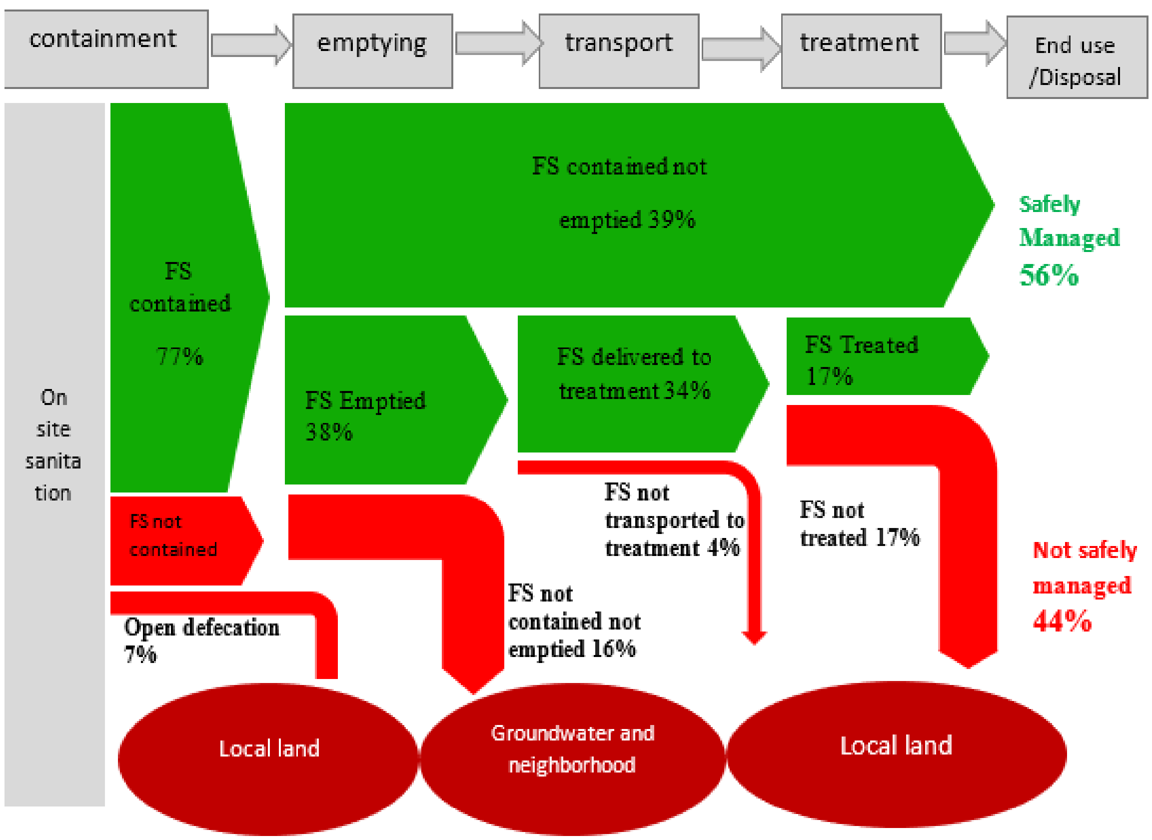


Figure 18: Citywide sheet flow diagram

As discussed in the previous sessions using a primary data from the household survey, key informant interview, FGD, visual inspection, and field observation along the sanitation service chain, the above citywide SFD was constructed for Kombolcha town as presented in Figure 20. The on-site containment system is shown on the left, with transitional steps and primary destinations of the FS shown along the sanitation service chain (SSC) shown to the right.

As Figure 18 indicated, there is complete coverage via on-site sanitation (93%) and 7% open defecation. Out of which 77% contained and 16% not contained on-site in the containment stage. Even though 77% of FS considered as contained on-site at present, beyond there is an increase in levels of groundwater contamination risk due to increased reliance on poorly constructed unlined pits and groundwater table occurrences in the town. What is clear from the SFD is also that almost half (56%) of fecal sludge in the town is safely managed i.e. effectively managed. Farther than 56% effectively managed FS, only 17% of fecal sludge passes through the sanitation service chain and considered as safely/effectively managed. Whereas the fecal sludge that remains unemptied and remains within onsite sanitation technologies without risk to public health or environmental contamination through groundwater pollution or direct exposure is considered as effectively managed (39%).

It's also shown that the households with a containment facility that could be emptied (78%), only less than half (37%) of these facilities are reported as actually being emptied as described in the above emptying session and Figure 18. The implications of the SFD along the SSC discussed further in Section 4.2.4.

4.2.4 Identified Gaps or Problems along the sanitation service chain

The most important starting point for identifying the weaknesses of existing services is the shit flow diagram as it determines how well the fecal waste is managed through existing sanitation services networks. The SFD highlights the "problems" or "gaps" of the fecal sludge, indicating areas where interventions are needed to improve the current situation.

Taking the substantial problems which cause to 44% unsafely managed fecal sludge in Figure 18, it is possible to identify feasible solutions to address them, based on results from the FSM study through discussions with concerned bodies within the town. The gaps along SSC discuss as follow.

i. Problems along with the storage/containment system

☞ **Poor toilet construction technologies and management**

As the HH survey identified 35.8% toilets were not well constructed and/or made of a non-durable material like rough or unfinished wooden, plastic/cloth or other semi-permanent materials whereas 1.6% toilets were haven't superstructure. (Appendix 4, Figure 4.11). In addition, some of the toilets were not kept clean and where excreta remain on the toilet and/or surfaces of the toilet room. It has been discussed in 4.3.3 session. This situation leads to health hazards and discussed in section 4.3.

☞ **Leachate from pit or tank to groundwater**

As shown in the onsite sanitation session 4.1.2, most septic tanks and pit latrine's containment system collects the sludge from the user interface into unlined/partially lined walls where there is a high groundwater that made the pit latrines or septic tank a major causes of groundwater pollution that used for local drinking-water sources or used for washing clothes, flushing toilets, and washing purposes 3.2% and 3.8% respectively as discussed in section 4.2.1.

☞ **Poor rehabilitation works**

As the held observation during household survey showed the existence of limited or no rehabilitation works on a toilet facility; as a witness, the study showed that 3.8% of toilet containments were failed, damaged or collapsed or flooded. During the household observation, it was observed that households having collapsed toilets, constructed another user interface and letting the excreta into the collapsed toilet rather than construct a new one (Figure 19). This situation leads to health threats through direct exposure to excreta.

Figure 19: Collapsed pit latrine toilets

ii. Problems along the emptying stage

☞ Limited access to pit or tank

The access road for emptying equipment was determined by 7.8% of household's sanitation facilities were poor access for only accessible to hand-carried emptying equipment and 11.5% of toilet facilities have equitable access for both small manual & mechanized emptying equipment. However, only large vacuumed trucks are currently giving emptying services. Consequently,19.3% of household toilet facilities in periphery and slum areas are unable to get emptying service and enforced to manually evacuate or abandoned when full which is unsafe emptying methods that pose significant health and environmental hazards.

☞ Inappropriate emptying equipment

The primary preference of the emptying truck is the municipality vacuumed truck due to its reasonable/affordable emptying cost, 500 ETB per trip with $8m^3$ volume capacity. However, only one vacuumed truck did not meet the emptying demand of the municipality and results in a long period of waiting time for emptying or use alternative private service providers which costs three to four (1200-2200 ETB) times the municipal emptying charge. As a result, 5.8% of households reported the occasions of pit overflow due to lack of emptying service when needed. The municipal vacuumed truck operator reported that the average time taken to get desludging service from the time of placing a request for service was one to two weeks, but the community reported as they wait for some months to get the emptying service. And results in pit/tank overflow that endangers the public health.

☞ **Users low affordability for pit emptying**

The household survey result showed that the households who believed their toilet facility need an improvement, 51.7% had no plan to improve their facilities. Among 51.7% of households, 70.8% of their biggest challenge to not plan for facility improvement was lack of financial resources. In relation to the affordability, low-income householders do not have the financial resources to build a good latrine that could be easily and safely emptied and also, they find the emptying services expensive.

iii. Problems along fecal sludge treatment stage

The interview held with sewerage service department head/plant supervisor, plant security persons or attendants and the held plant site observation identified the following encountered problems.

☞ **Overloaded treatment plant and fails to works optimally**

The drying beds received fecal sludge from Dessie town, Harbu and other neighboring towns in addition to the Kombolcha municipality (KII 1). As a result, the drying beds being potentially inadequate, the treatment plant is not being effectively managed. Even though its current situation does not appear to be creating an environmental risk, there may be greater flows of untreated fecal sludge downhill to the Borkena river due to the receiving daily additional overload of FS from nearby towns. The condition of the drying bed cells was found to be poor and damage to retaining walls as well as common walls. In addition, there was also plant growth on the drying beds at rest (Appendix 4, Figure 4.5a, b & 4.10a).

☞ **Nonfunctional Bar screens/prolonged drying period**

At the inlet of the drying beds, no functional screening unit as the result, the vacuumed trucks directly disposed of the sludge onto drying beds without screening. This situation results in the accumulation of rubble and trash which clogs the liquid to not percolate through the bed consequently the drying period of the sludge has been prolonged(Appendix 4, Figure 4.4a). It has been discussed in a later section.

☞ **Limited or No dry fecal sludge removal practice**

No periodic removal of cake or dry fecal sludge from the drying beds. As per the observation held at the plant, there were grown plants at the drying beds at rest. As the plant security person interview shows, when the sludge got dried the volume of the drying bed decreases and the vacuumed trucks unload the sludge onto the drying bed with dried sludge/cake once again. As a result, the rewetting of the sludge and prolonged drying period was a problematic situation.

- **Non-functional sanitary landfill**

The sanitary landfill was constructed primarily for the storage of dried sludge/cake until it becomes safe or completely degraded biologically and physically to be safe for soil conditioning purposes. But the landfill is currently non-functional and fully transformed into natural areas. As a result, it makes difficult the temporal storage of cake/dried sludge for further treatment and resource recovery activities. This results in the risk exposure to the environment.

Future scenarios of the FSTP

A maximum of 7 vacuumed truck (6 private and 1 municipal) operate throughout the year (KII 1, 2019). According to the KTWSSA sewerage service department document, the volumes of fecal sludge potentially reaching the plant in all months the year was recorded from 2017 to 2019 (Annex 3). The average yearly trips or frequency of vacuumed trucks were 1819, 2546 and 3086 tankers of fecal sludge with an average volume of 7m^3 (12,733 17,822 & 21,602) m^3 respectively for three successive years. The future required bed area (the capacity of the plant) and the yearly volume of fecal sludge can be estimated from the above-given data.

Kombolcha town is an industrial area with vast scope expansion and population increase which results in a high accumulation of sludge from year to year. Thus, it’s appropriate to predict the volume of sludge accumulation for the year 2020, 2025 and 2028 (end of the plant design period) using the geometric increase method.

Table 11: Yearly volume of sludge accumulation

Years	Sludge volume (m^3)	Increment	Geometrical increase rate of growth
2017	12733		
2018	17822	5089	(5089/12733) = 0.399
2019	21602	3780	(3780/17822) = 0.212
Total			0.611
Average			**0.305**

Projected volume of sludge accumulation at 2020 = 21602 $(1+0.305)^1$ = **28,190.6 m^3/year**

Projected volume of sludge accumulation at 2028 = 21602 $(1+0.305)^9$ = **237,131 m^3/year**

Therefore, the daily volume of sludge accumulation in 2020 can be estimated 78 m^3/day and the daily volumetric capacity required is, therefore:

78 m^3/0.3m =**260m^2 /day** for Sludge loading height: 20cm (the typical depth of FS on a drying bed) and 10cm allowance depth for liquid.

The plant 3 drying beds with 22 cells having 280m^2 each; i.e. 6160 m^2 total area of the bed. Thus, it takes 24days to get full of all drying beds. However, this is only true where all the beds are empty. This situation together with prolonged periodic removal of cake or dry fecal sludge endangers the plant even in the fiscal year 2020 unless the proper measure is taken. The previous observations and interviews held with plant attendants proven incoming problems that's why the cake removal frequency reaches 4 to 6 months due to clogged pore spaces of drying beds. If this management trend continues, the problem becomes 8 times what happening in 2020 by 2028 at the end of the design period which means the plant begins exposure to significant environmental risk hazard events in 2020 for the nearby Borkena river that situated 50m from the downstream side of FSTP.

4.3 FSM Related, Public Health Hazards or Risk Exposures

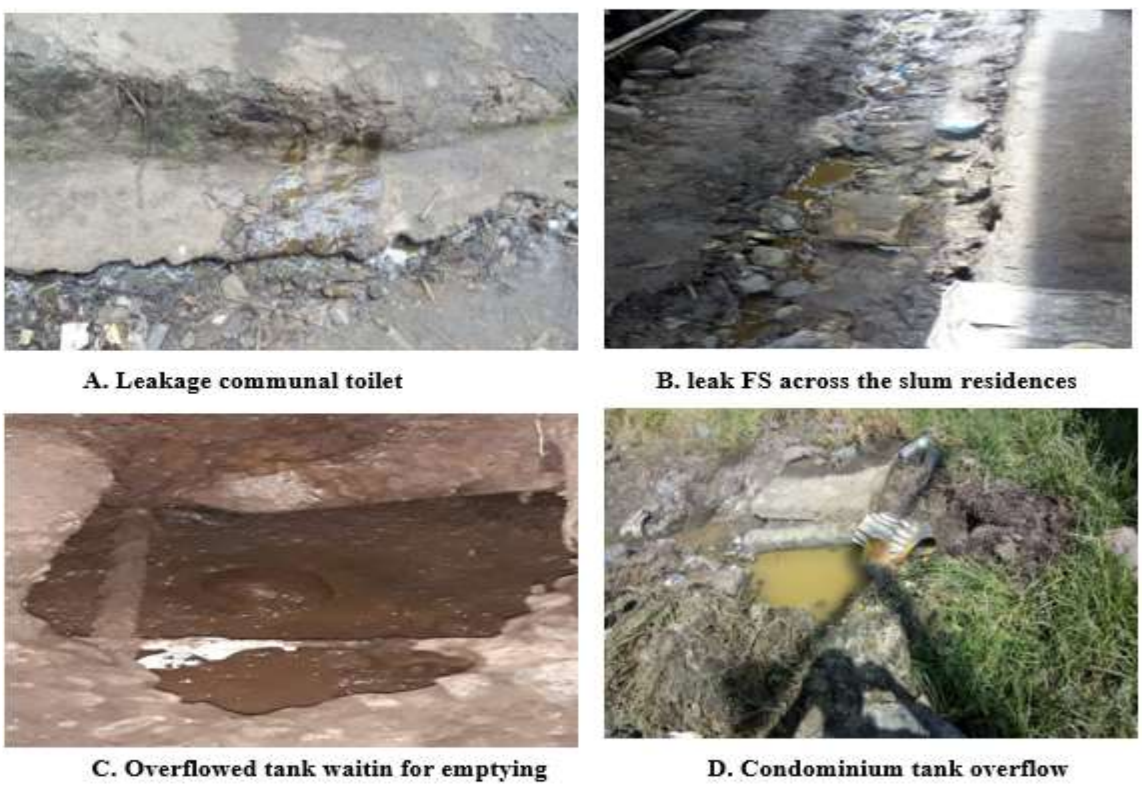
Pinpoint the extent of public health and environmental risk exposures resulting from poor fecal sludge management services is one component of this study. This session seeks to identify the public health hazards from wider range perspectives in addition to the identified FSM gaps consequence via mapping excreta flows along the sanitation service chain. The highlighted gaps in SFD indicated the incidence of health hazards. Following this, the public health risk exposure valuation in the municipality was carried on the following segments:

- Pit/tank overflow and leakage incidences
- Tank/pit latrine effluent connections into open/drainage canals and water bodies
- Groundwater contamination occasions
- Hygienic use and maintenance user interfaces
- Children feces management practices
- Solid waste management practices
- Hand washing practices after defecation

4.3.1 Pit/tank overflow and leakage incidences

The held transect walk in low-income areas identified the existence of pit overflows and leakage from the communal toilet. As the residents reported and the interview held with health extension works ensured, from 25 up to 30 households shared one seat of the communal toilets in this area. Lack of proper maintenance together with rapid pit filling rates and late emptying service results in pit leakage and overflow through kebele and condominium houses as can be seen in Figure 20.

The transect walks also identified locations in which a septic tank in condominium residents and communal latrines in slum areas had some form of fecal contamination. This was either from feces accumulating around the facility, or the facility itself overflowing (Figure 23, C and D). Follow-on those problems, the study identified pit latrine or tank overflow and leakage from those technologies (Figure 20, A and B) as a source of public health and environmental hazards or risk exposures.



A. Leakage communal toilet

B. leak FS across the slum residences

C. Overflowed tank waitin for emptying

D. Condominium tank overflow

Figure 20: Pit latrine or septic tank leakage and overflows

4.3.2 Tank/pit effluent connections into open/drainage canals and water bodies

The held FGD with community representatives shows illegal pit effluent connections into mainly water bodies and drainage canals during rainy seasons. During the discussion, the participants reported the practice of pumping liquids from septic tanks and disposed into drainage canals during rainy seasons due to raised groundwater.

The held observation of toilet facilities during HHs survey also identified some households who refused to show their toilet facilities in suspected areas for illegal disposal which was an indication for their illegal practice; even though it's difficult to conclude (Figure 21). As can be seen from the above 4.2.2 session Table 9 lined pits and tanks that letting FS discharge to open drain/water body with pipes estimated as 9.5% (it could be expected to be higher than reported value) of HHs practice the situation (Figure 21). Among those water bodies Berberie river, worka river, arawule river, and other water bodies are found in different localities of the town which are in turn connected to the Borkena River that everyone can be accessible for washing their bodies and clothes.

Figure 21: Illegal pit latrine and septic tank discharges through an open drain

4.3.3 Hygienic use and maintenance of sanitation facilities:

The direct observation of the toilet facility during the household survey has identified the household's toilet functionality, cleanliness (if free from any fecal smears in/on pan & floor and all walls or not) and water availability within the toilet. The result shows that 69.5%

of observed latrines had a cleanable slab and 13.6% had either feces or feces plus urine, visible contamination on the floor slab whereas 31.3% urine only visible. 98.8% were reported to be functional at the time of observation. Thus, this situation leads to health hazards or risk exposures.

4.3.4 Children feces management practices:

The household survey result pinpointed the presence of potential health risk exposures to both households and the community as a whole through unsafe children's feces disposal practice. Out of the sampled household respondents, 43% of households reported that their children's feces are put/rinsed into the latrine. As shown in Figure 22, 38.4% feces of children under 5 years old were thrown out with garbage/solid waste. The remaining 18.6% of households practiced unsafe children feces disposal ways (7.6% disposal of children feces inside the yard & 11% children feces disposed indiscriminately outside the premises).

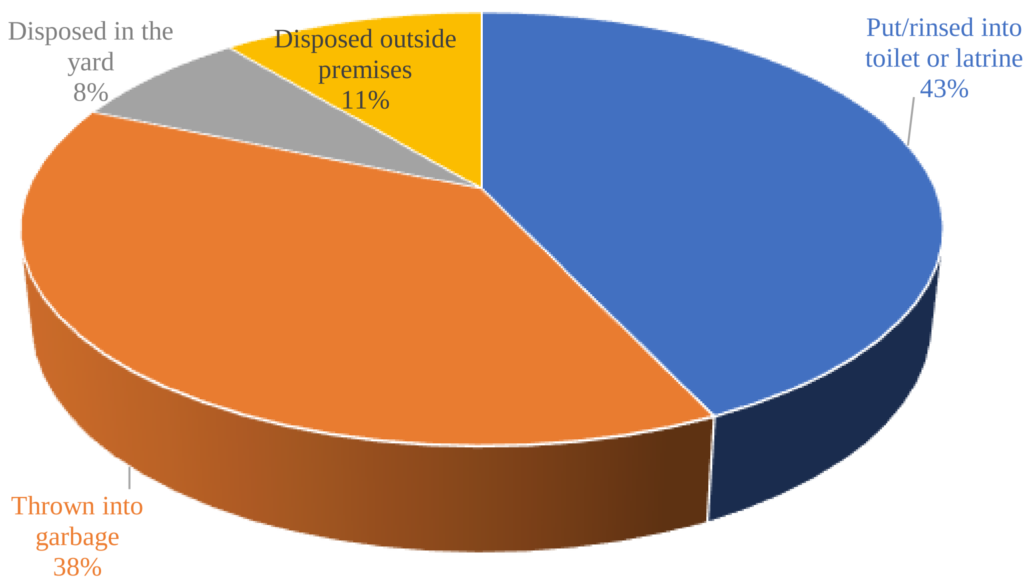


Figure 22: Children feces management practices

Children's feces being thrown out with solid waste and dumped into water bodies, roadsides and drainage canals which can be accessed by children and others for washing their bodies, scavenging in the garbage to recover resources, to walk and play over it.

The study result showed that 53% of children feces unsafely disposed of (Figure 22). This result shows the spread of diseases with direct or animal contact according to WHO/UNICEF (2013), that states the proper disposal of children's stool or feces is important in preventing the spread of diseases; in another hand, If feces left uncontrolled, diseases spread by an animal or direct contact.

The study result somewhat in line with the other study on demographic and health survey (CSA and ICF, 2017) that find 40% of children had their stool disposed of safely, either by using a toilet or having the stool rinsed or put in a toilet or latrine. In addition, the current study shows also 38% of children feces thrown into garbage unlike the previous study (18%) and 19% feces left in the open, whereas the previous study shows 26% in contrast. Generally, 53% of the current children's feces way of management causes the spread of diseases.

4.3.5 Solid waste management

As per held field observation, household survey, and KII result identified most of the solid wastes that are generated in the town remain uncollected and simply dumped in drainage canals, roadsides, river courses and gorges. The observation and interview with carrying and dumping service providers identified that daily worker comes in to contact with households to carry and dump sack with solid wastes and charge 10 to15 ETB per sack. These daily workers dump the waste into the nearest river courses or valley to get additional money from other households as well. Those workers do not use any personal protective equipment (observation). As these workers reported most households are not willing to pay rather, they remove themselves. The present finding in line with the previous study (Yimer & Sahu, 2014) that reported the Kombolcha town's solid waste management was being paid a little devotion and results in environmental degradation and public health risks due to uncollected disposal of waste on the streets, market places, drainage canals, and riversides by indiscriminately dumped waste and pollution of water resources.

As discussed in the above 4.2.4 session households dispose of child feces with solid waste, this could introduce a certain level of risk exposure, particularly in areas with informal solid waste collection services, or where children play in drains and in or around solid waste piles.

4.3.6 Handwashing practices after defecation

Data were collected by observing whether a handwashing station with water and soap is available or not throughout the household survey. The survey findings show that handwashing stations were available rarely in some households. A large number of households were using water only to sanitize their hands after defecation. 72% of the population use stored water with a container or bucket for anal cleansing as well as for washing hands (Figure 23). Whereas 7% of households have handwashing stations (basin), of which 3% of households familiarized to wash their hands with soap. Totally 12% of households familiarized to wash their hands with soap including households who stored water with container/vessel for anal cleansing or handwashing. The remaining 88% of households not habituated handwashing with soap (Figure 23).

The Ethiopian demographic and health survey (EDHS) find out a place for handwashing in 60% of households (81% in urban areas and 55% in rural areas) as a country level. Soap and water, the important handwashing facilities 28% of urban households and 7% of rural households. Unavailability of water, soap, and other cleaning agents were 43% of urban households and 68% of rural households (CSA and ICF, 2017). The current study differs from this EDHS in all results i.e. hand washing stations, habituation of handwashing with soap as well as unavailability of water, soap, and other cleaning agents. This much difference may be due to the town level and country-level results. The study result signifies the health risk exposure events due to lack of handwashing with soap after defecation (88%) as shown in Figure 23.

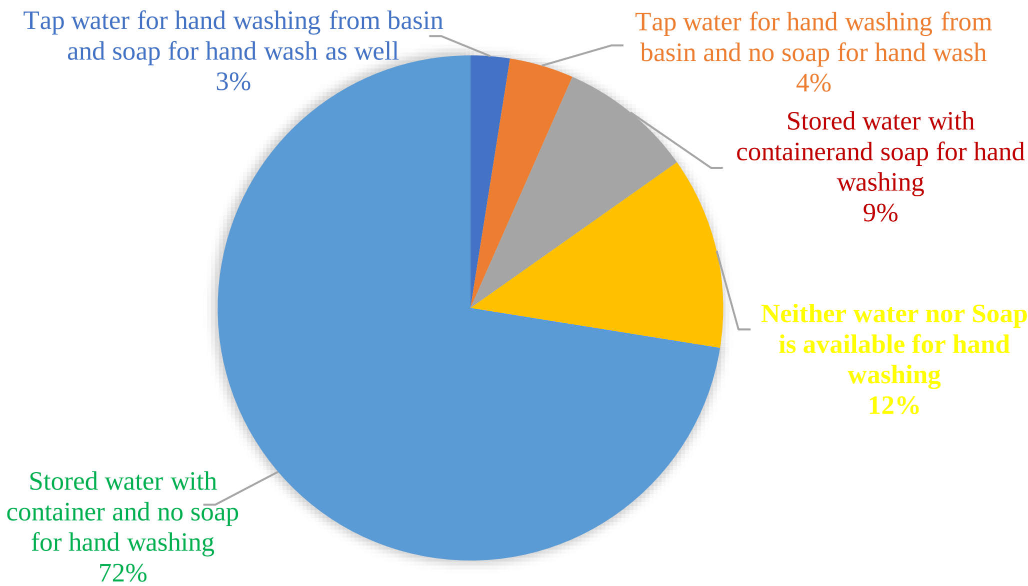


Figure 23: Household's handwashing practices

4.3.7 Groundwater contamination occasions

Groundwater contamination is suspected for health risks exposures at medium risk level from the movement of pathogens and subsequent interaction with the groundwater. The household survey and observation groundwater source within the household's property showed 3.7% of the households found in high groundwater table areas had their own water source. However, almost all households in this area have access to an improved water point. As a result, those households use their groundwater source for washing clothes, flushing toilets, and washing housewares rather than used as drinking water sources. However, 3.2% of households relied on spring water sources located in periphery areas (cluster 9) whose sanitation technologies are unlined or traditional pits allowing fecal sludge to leach into the surrounding soil and groundwater that pose significant groundwater risk.

Generally, 3.2% of households exposed to significant groundwater contamination risk where FS goes/leach into the spring water sources as can be seen from groundwater contamination risk estimation session 4.2.1. Whereas 3.7% of households exposed to medium-risk categories were there some containment in a pit or septic tank, but those pits/tanks are unlined/permeable, allowing FS to leach into the surrounding soil and groundwater that used for domestic purposes (e.g. washing clothes, flushing toilets, and washing housewares) rather than for drinking purpose. These scenarios still represent a risk, but it is somewhat lower than contact with fresh FS as in the high-risk category above.

4.4 Public Perceptions Towards the Current FSM Practices

An assessment of community perceptions in Kombolcha town was carried on household satisfaction with their toilet facilities and biggest challenges to improve sanitation facilities, attitudes towards government subsidy, intention for future planning and level of satisfaction with the performance of service providers.

4.4.1 Household proposal to improved Sanitation Management

The household survey result showed that the majority of households (84.4%) believed that their current toilet facility needs improvement. Whereas the remaining 15.6% of the community supposed that their current sanitation facilities are improved enough. When those households who had toilet facilities that need improvement asked what kind of improvement is needed for their facility, the householders had these to say:

- Replace the current facility with flushable user interface connected to a septic tank

- ☞ Install handwashing basin
- ☞ Reconstruct the facility with a permanent wall, roof, and cleanable slab
- ☞ Reduce the number of households per seat of the communal toilets so as to keep clean and easily accessible.
- ☞ Rehabilitation of the facility superstructures

Moreover, the households who had toilet facilities that need improvement was questioned one again if they have a plan to improve their sanitation facilities in the near future, and they answered as follow:

- ☞ No plan (51.7%)
- ☞ Have a plan to build a new toilet (20.5%)
- ☞ Have a plan to upgrade or rehabilitate a facility (27.8%)

The household survey result showed that 48.3% had a plan on whether to construct a new toilet or rehabilitate the existing one and their main reasons for households to start planning for improved sanitation were:

- ☞ The current facility is not safe and improved enough
- ☞ To not be ashamed when we have visitors
- ☞ Repugnance and smelly conditions of the current facility

Among the households from which believed their current toilet facility needs improvement, 51.7% had no plan to improve their sanitation facility. As these households reported, their biggest challenge to not plan for facility improvement was lack of financial resources (70.8%). Whereas 26.4% of households described their challenge to improve facility was not only financial constraint but also lack of place for own toilet construction, lack of willingness to share facility improvement costs with other households who use communal toilets, and lack of access road for emptying equipment. The remaining 2.8% of the community's biggest challenge was a lack of household member's interest to improve the current facility.

Need for government support

From all sample households, 84.4% was asked their opinion about government subsides/support to improve their toilet facilities except those households who considered their facility as improved enough. From those questioned households, 90.7% answered that the government should support the urban poor communities to improve their sanitation facilities in different ways. Those households also questioned what would they expect as a subsidy from the government and they answered what they expect as follow:

- Financial support for new construction/rehabilitation of toilets (if possible)
- Material support (iron sheet, Cement, etc.)
- Technical support (consultation during the construction of facilities)
- Additional communal toilet construction
- Rehabilitation work for existing condominium septic tanks & communal toilets
- The access road that could allow the vacuumed trucks to empty the toilet
- Lessen or free pit emptying service fees

The remaining 9.3% of households answered as they didn't except any government support.

4.4.2 Household satisfaction with current services

This assessment was addressed through household survey questions in two ways. Firstly, households were questioned to rate their satisfaction level with various aspects of the sanitation facilities used, including quality of construction, ease of access, privacy and cleanliness. Secondly, households which had used an emptying service the last time their pit or tank filled up, were asked to rate the service provider on price, overall service quality, and ease of obtaining service.

I. Level of satisfaction with toilet facilities

The household's questionnaire result showed that the majority of households (6.6-62% in all cases) stated being satisfied or very satisfied with the sanitation facility, across all four characteristics in the question. Dissatisfaction with all five characteristics (quality of construction, ease of access, privacy, cleanliness, and distance to the toilet) their toilet facilities were in a range of (17-43%) as shown in Figure 24.

The level of satisfaction with the sanitation facility was driven by the ability of households to invest in the improvement and maintenance of their facilities, which includes emptying of the pit/tank. Overall, 76.5% households were generally satisfied or very satisfied with the distance to their toilet facilities rather than for the quality of its construction which almost half (56.8%) of the total respondents dissatisfied; because of most of the households in the town reliant on pit latrine technologies for temporary or permanent basis (Figure 24).

It’s possible to say that some of the respondents accept their pit latrine technology as constructed with quality.

Furthermore, the other comparatively high dissatisfied values were ease of access to a toilet (26%). This level of satisfaction was due to the high number of shared toilet coverage of the town. In addition, the cleanliness of the household’s sanitation facilities (43%) was more disappointing when compared with other accesses (toilet distance, privacy, and ease of access to their tank) (Figure 24).

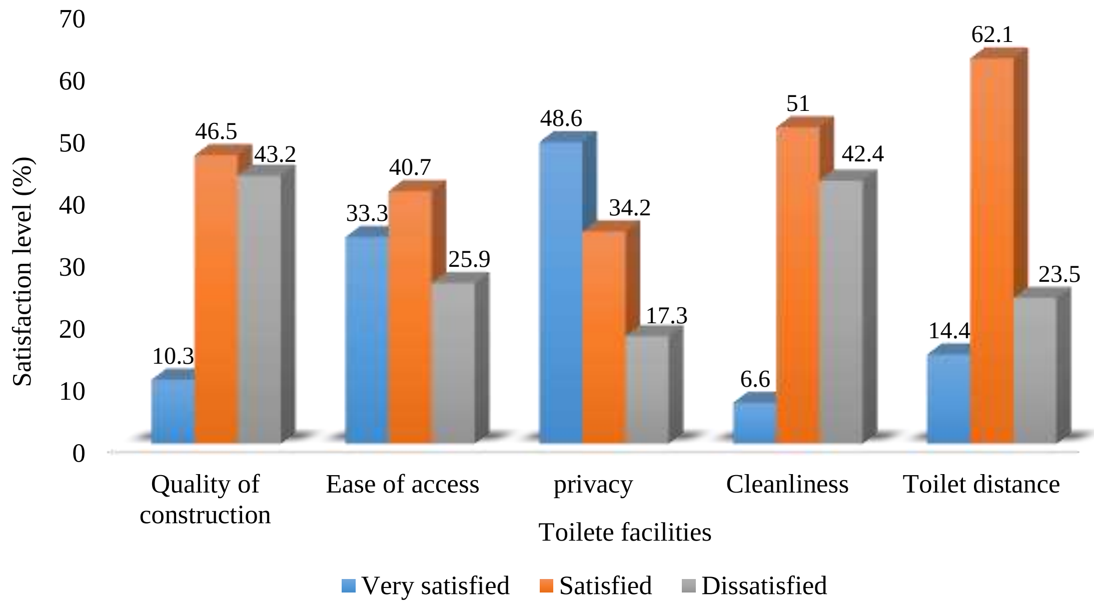


Figure 24: Household’s level of satisfaction with the current toilet facilities (%)

II. Level of satisfaction with the performance of service providers

For the households who experienced in a pit/tank filling up and emptied their facility to reused again using a service provider (37% of respondents), satisfaction levels (either satisfied or very satisfied) were between 33.3-92.2% for all three categories of service provision (Figure 25). Whereas the levels of dissatisfaction were between 7.8% to 66.7% in all three categories, the maximum level of dissatisfaction was standing for easy obtaining emptying service (66.7%).

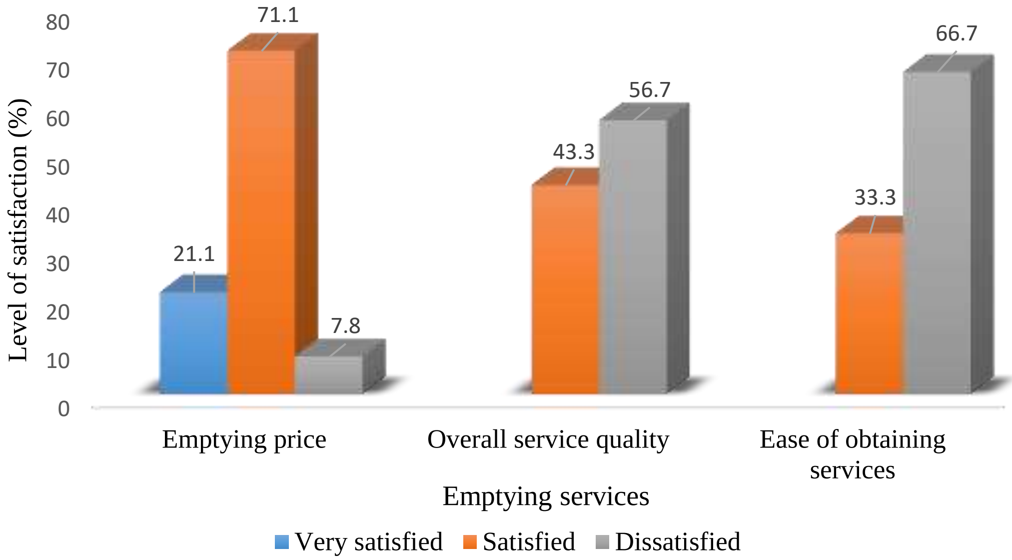


Figure 25: Household's satisfaction with the performance of a service provider (%)

Related with emptying prices the highest level for dissatisfaction was 7.8% (Figure 25); this was because almost all of the households use the municipal vacuumed truck to get emptying service. During the FGDs related to the issues of price and gaining services, participants noted that households can be waiting up to 3 months for a municipal truck to be available to provide emptying services especially when the truck gets maintenance. Whereas the private truck operators have a much greater capacity to respond and often charge a much higher due to transportation cost as they come from Dessie town. The held interview with emptying service providers also ensured the FGD participants remark. As a result, the flat rate per emptying is typically 500 ETB for the municipality vacuumed truck emptying service, compared to the variable charge between1200 to 2200 ETB for the private provider service. This condition makes the HHs to dissatisfied in gaining service and satisfied with the emptying price as their primary preference is a municipal truck.

4.4.3 Household's judgments to improve the current FSM practice

Households were asked their thoughts about what could be done to improve the current sanitation situations especially excreta management practices in their locality and Kombolcha as a whole and they had these to say:

- All sanitation lawbreakers (open defecation practitioners, those who connect their toilet into canals, etc.) and people who refuse to construct a toilet facility when building their house should be prosecuted

- ☞ Rehabilitation of existing and construction of more communal toilets in slum areas and public toilets at vantage points with less charge/free charges for urination and defecation
- ☞ Implementation and enforcement of sanitation bye-laws and regulations with effective supervision, inspection and monitoring of sanitation facilities and services
- ☞ The municipality should provide subsidies for low income HHs for the construction of toilet facilities together with awareness-raising on the need to have HH's latrines.

The above household opinions were evident for the need for subsidies for low incomed HHs and rehabilitation of existing PTs and communal toilets as well as enforcement of sanitation bye-laws with proper supervision, inspection, and monitoring of sanitation facilities and services were a probable solution to the fecal sludge management problems.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The key structural components of the study included existing sanitation arrangements & FSM practices, developing excreta flow diagram (SFD), identification of problems along the sanitation service chain and health hazards due to poor FSM practices, and assessment on the beneficiary perception of the current fecal sludge management practices. From the analyzed results and discussions, the following conclusions have been drawn:

Most of the households in Kombolcha town own a private house; however, 75.7% of households reliant on shared toilets with two and above households. The level of sharing toilets was raised due to shared toilets between house owners and households with rental classrooms. Generally, there are five main toilet technologies of households in the municipality; Cistern flush toilets, pour/manual flush toilets, VIP, Pit latrine with and without slab. Among these technologies, the dominant toilet technology is a pit toilet with and without slab (67.1%).

Most of the identified on-site sanitation technologies are emptiable (78%); however, only less than half (37%) of excreta from onsite sanitation technologies are collected and transported using cesspit emptiers or vacuumed trucks. The excreta discharged from those emptiable technologies disposed of and treated using unplanted drying beds. However, the FSTP was not optimally working due to a lack of proper supervision, operation, and maintenance.

The Shit Flow Diagram (SFD) was developed based on the existing containment technologies, groundwater contamination risk, emptying, transport and FS treatment end use/disposal practices along the sanitation service chain. The developed SFD result presents 56% of fecal sludge is effectively managed and 44% is unsafely managed i.e. poses health risk exposure directly or by contaminating the groundwater sources.

The main sources of the public health and environmental risk exposures were resulting from pit/tank overflow and leakage incidences, tank/pit latrine effluent connections into open/drainage canals and water bodies, groundwater contamination occasions, hygienic use and maintenance user interfaces, children feces management practices, solid waste management practices and handwashing practices after defecation.

The majority of households in Kombolcha town believed that their current toilet facility needs improvement. However, most of those households had no plan to improve their sanitation facilities due to a lack of financial resources. Furthermore, households also remarked the need for subsidies for low-income HHs, rehabilitation of existing PTs and communal toilets as well as enforcement of sanitation bye-laws with proper supervision, inspection, and monitoring of sanitation facilities and services to ensure a proper fecal sludge management practice.

5.2 Recommendations

Based on the findings of the study, the following recommendations are suggested

- Sanitation bye-laws and building code regulations should be enforced and standards of latrines must be set to address the quality of different components of the latrine (tanks, pits, pit lining, slabs, etc.), and construction that promote hygienic standards.
- Rehabilitation works and additional construction of public and communal toilets should be done so as to promote and safeguard public health. The municipality should also undertake regular monitoring and inspection of the facilities.
- Increasing the emptying capacity should be planned through a price adjustment mechanism, especially for private emptying service providers. For periphery and slum areas, there should be an introduction of small-scale emptying equipment.
- The plant supervisors must be fully trained to understand and carry out their roles to ensure good practice of operation, maintenance, and oversight of the facility, to achieve optimal treatment capacity of the plant.
- There should be an integrated bottom-up approach and involving all beneficiaries of stakeholder’s participation in the planning to the implementation phases of fecal sludge management services. This can be achieved by consulting households in the development of city-wide sanitation plans.
- For a comprehensive assessment for the purpose of intervention planning, there should be a city service delivery assessment (CSDA) in addition to SFD analysis in conjunction with public health risk assessment.

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APPENDIX

Appendix 1: Household Interview Questionnaires

Part 1: Household information

1. Name of the family head……………………………Date of interview……………
2. Address of the household (kebele, ketena and house number) …………. ……………
3. What is the household head that completed the highest level of education?

☐ 1.No formal education	☐ 5. Preparatory (grade 11-12)
☐ 2. 1– 4 grades complete	☐ 6. College
☐ 3. First cycle (grade 5-8)	☐ 7. Technical/vocational
☐ 4. Second cycle (grade 9-10)	☐ 8. University

4.What is the average total monthly income of the household? This includes income earned by all members of the household and all sources of income.

☐ 1. Below 500 Birr per month	☐ 4. 2001 – 3000 Birr per month
☐ 2. 501 – 1000 Birr per month	☐ 5. 3001– 4000 Birr per month
☐ 3. 1001– 2000 Birr per month	☐ 6. Over 4000 Birr per month

5.Is this house/residence owned, rented, rent-free?

☐ 1. private house	☐ 4. kuteba rental
☐ 2. private rental	☐ 5. Take care of the house for someone else
☐ 3. kebele rental	☐ 6. Occupy family house

Part 2: Sanitation service chain current situation

2.1 Containment system arrangements

1.When was your on-site sanitation facility (septic tank, pit latrine….) constructed?

☐ 1. Within 5 years

☐ 2. 5 to 10 years

☐ 3. 10 to 20 years

☐ 4. Before 20 years

2.Is the toilet private, public or shared (more than one household)?

☐ 1.Private (only one household)

☐ 2.Private (more than one household)

☐ 3.Shared (more than one household)

☐ 4.Public toilet

3.If the toilet is private and used by more than one household, what is the number of households?

☐ 1.Two

☐ 2.Three

☐ 3.Four

☐ 4.More than four households

<u>Observational questions (4,5,6,7&8)</u>

4.Is there any water (groundwater) source available on your property?

☐ 1.Yes

☐ 2.No

5. If yes, for question 4, observe and record (if not possible, ask the question) the following points.

5.1 What is the water (groundwater) production technology used in your property?

☐ 1. Protected boreholes, protected dug wells or protected spring

☐ 2. Unprotected boreholes, dug wells or springs

5.2 What is the average depth at which the groundwater source is available in your property?

☐ 1.Less than 5m

☐ 2.5m to 10m

☐ 3.Greater than 10m

5.3 Is the sanitation facility located uphill of groundwater sources?

1. Yes, ☐ 2. No ☐

5.4 How close the toilet to a groundwater source?

☐ 1.Less than 5m

☐ 2.5m to 10m

☐ 3.Greater than 10m

6.Observation of wastewater discharge points: ask the question about household wastewater discharge points, If the respondent refused to show.

☐ 1.Piped sewer ☐ 5. soak-away/cesspit/septic system

☐ 2.Directly to, lake or river ☐ 6. sanitation facility

☐ 3.Premises yard/garden ☐ 8. street surface

☐ 4.open channel ☐ 9. Others (specify…)

7.Would you kindly show me your toilet, please? ☐ 1.Yes, 2. No ☐

8.If yes, for question 7, observe and record (if not possible, ask the question) the following points.

8.1 Is the toilet functioning/working? ☐ 1.Yes, 2. No ☐

8.2 Does it have a cleanable slab? ☐ 1.Yes, 2. No ☐

8.3 What is the material of the superstructure?

☐ 1. Brick/wood – or other permanent material

☐ 2. plastic/cloth – or other semi-permanent materials

☐ 3. No superstructure

8.4 Does it have a roof? ☐ 1.Yes, 2. No ☐

8.5 Does it have a door or other materials that provide privacy? ☐ 1. Yes, 2.No ☐

8.6 Is the floor or slab contaminated with feces or urine?

☐ 1.Feces only, (both feces and urine,) visible

☐ 2.Urine only visible but not feces

☐ 3.Neither feces nor urine visible

8.7 Observations of handwashing facilities:

Interviewer: Mark all for the facilities that you observe <u>without reading out loud</u>.

☐ 1.Tap water for handwashing from basin and soap for hand wash as well

☐ 2.Tap water for handwashing from the basin and no soap for hand wash

☐ 3.Stored water with bucket and soap for handwashing

☐ 4.Stored water with bucket and no soap for handwashing

☐ 5.Neither water nor Soap is available for hand washing

8.8 Can emptying equipment get access into the compound?

☐ 1. Poor access, only accessible to hand-carried emptying equipment

☐ 2. Equitable access for both small manual & mechanized emptying equipment

☐ 3. Good access for medium and large-sized mechanized emptying equipment

8.9 What kind of toilet facility does the household usually use?

- [ ] 1. Cistern flushes
- [ ] 2. Pit latrine with slab
- [ ] 3. Hanging latrine
- [ ] 4. Pit latrine without slab
- [ ] 5. Pour/manual flush
- [ ] 6. Composting toilet
- [ ] 7. VIP latrine
- [ ] 8. No toilet

If no toilet, what is your habit (shared, open space, public toilet, other)?

<u>Household based questions (9, 10 and 11)</u>

9. Where do the contents of this toilet discharge to?

- [ ] 1. No onsite container
- [ ] 2. Septic tank
- [ ] 3. Fully-lined tank
- [ ] 4. Lined tank with impermeable walls and open bottom
- [ ] 5. Lined pit with semi-permeable walls and open bottom
- [ ] 6. Unlined pit
- [ ] 7. Pit (all types), never emptied but abandoned when full and covered with soil
- [ ] 8. Pit (all types), never emptied, abandoned when full but not sufficiently covered
- [ ] 9. Toilet failed, damaged, collapsed or flooded
- [ ] 10. Others (specify) ………………………

10. Where does the containment outlet connect to?

- [ ] 1. Decentralized combined sewer
- [ ] 2. Decentralized foul/separate sewer
- [ ] 3. Soak away pit
- [ ] 4. Open drain or storm sewer
- [ ] 5. water body
- [ ] 6. open ground
- [ ] 7. 'Don't know where'
- [ ] 8. No outlet or overflow

11. What is the main source of drinking water for members of your household?

- [ ] 1. Piped into dwelling
- [ ] 2. Piped to yard/plot
- [ ] 3.Protected spring
- [ ] 4. Public tap
- [ ] 5. Protected dug well
- [ ] 6. Unprotected spring
- [ ] 7. Rainwater
- [ ] 8. Surface Water
- [ ] 9.Unprotected dug well

2.2 Emptying information

1. Has your on-site sanitation system (pit or septic tank) ever filled up?

- [ ] 1.Yes, if yes, when last time……………
- [ ] 2.No

2. How did you recognize that containment (septic tank or pit) was full?

☐ 1. Containment was overflowing and Spreading foul odor

☐ 2. Emptying at regular interval

☐ 3. Because of regularly check

☐ 4. Other (specify) ………………………………….

3. Has the toilet ever overflowed? If yes, what was the reason for this?

☐ 1. Blocked

☐ 2. Flooded with rising groundwater table

☐ 3. Flooded by stormwater

☐ 4. No money to empty

☐ 5. Emptier not available when needed

☐ 6. Not ever overflowed

4. What did you do when the pit or septic tank filled-up last time?

☐ 1. Emptied and reused pit/tank

☐ 2. Abandoned and pit/tank remains unsealed

☐ 3. Abandoned with soil or sealed cover on pit/tank

☐ 4. Covered and used alternative pit

☐ 5. Others (Specify) …………………………

5. Last time if it was emptied, who did the emptying?

☐ 1. Member of household

☐ 2. The informal provider (individual)

☐ 3. The formal provider (company / NGO)

☐ 4. The formal provider (municipality)

☐ 5. Others (specify) …………………………..........................

6. How was it emptied?

☐ 1. By hand, using buckets or similar

☐ 2. By hand, using a manual pump

☐ 3. Mechanically, using a small machine

☐ 4. Mechanically, using a vacuumed truck

7. If you have paid for the pit to be emptied, how much did you pay per trip or m^3?

☐ 1.Formal Private emptiers service provider ……................Birr

☐ 2.A formal emptying service provider (municipality)………Birr

☐ 3.Informal (manual) emptying service provider…………...Birr

☐ 4.other (specify)……….….. Birr

8. If it was emptied manually, where did it empty into?

☐ 1. Directly into drain/water body/field

☐ 2. Into a pit on the compound that is then covered

☐ 3. Into a pit on the compound that is left open

☐ 4. Directly into drum / open container if any

9. How long does it take for your pit/tank to require re-emptying?

☐ 1. Less than one year

☐ 2. 2 - 3 years

☐ 3. 3 - 6 years

☐ 4. More than 6 years

☐ 5. Other (specify)…………………………………………….................

Part 3: Community's Perception, & proposal for improved facility

1. Do you think that your toilet needs improvement?

☐ 1.Yes ☐ 2. No

2. If yes for question 1, what kind of improvement you want to have? (Mention all points)
3. If your answer is yes for question 1, are you planning to improve your sanitation arrangements in the near future?

☐ 1.No, we have no plans

☐ 2.Yes, plan to build a new toilet

☐ 3.Yes, plan to upgrade a toilet

☐ 4.Yes, others (Specify) ………………………………….

4.If your answer is yes for question 3, what made you start this plan?

☐ 1.To have my own toilet instead of public/communal toilets

☐ 2.The current one is not safe and improved enough

☐ 3.To not be ashamed when we have visitors

☐ 4.Repugnance and smelly conditions of the current facility

☐ 5.Any other (state)____

5.If No plans for question 3, what is your biggest challenge in improving your toilet facility?

☐ 1. Lack of finance/high cost of toilet construction

☐ 2. Lack of knowledge on how to do this

☐ 3. Lack of interest of other household members

☐ 4. Lack of skilled people to construct

☐ 5. Others (Specify) ……………………………………

6.Do you think the government should provide subsidies (support with money/materials) to those who had no money to improve their existing toilet facilities?

☐ 1.Yes, ☐ 2. No

7. If yes for question 6, what would you expect as a subsidy from the government?
8. What is your opinion about taking actions at the household level for fecal sludge related problems?

☐ 1. I am willing to take actions as much as I can

☐ 2. It's not a problem for me

☐ 3. It's not my responsibility

☐ 4. I have other main concerns

9. What do you think should be done to improve the current sanitation situations related to excreta management practice in your locality and Kombolcha as a whole? (Write all points)

Part 4: Hygienic practice and Health

1.When does your household practice handwashing? …………..

Interviewer: Mark for all mentioned without reading out loud.

☐ 1. Before eating

☐ 2. After eating

☐ 3. After defecating

☐ 4. Before feeding a child

☐ 5. Before preparing food

☐ 6. Others

2.When does your household use soap to wash their hands? ……………….

Interviewer: Mark for all mentioned without reading out loud.

☐ 1. Before eating

☐ 2. After eating

- [ ] 3. After defecating
- [ ] 4. Before preparing food
- [ ] 5. Before feeding a child
- [ ] 6. Other (………………………….)

3. For the children under age 5 living in the household, where did they usually defecate?

Interviewer: Mark for all mentioned without reading out loud

- [ ] 1. Used the sanitation facility
- [ ] 2. Went outside the premises
- [ ] 3. Used bedpan
- [ ] 4. Went in backyard
- [ ] 5. Used diapers
- [ ] 6. No children under age 5

4.How were the feces of children (under 5 years) usually disposed of?

Interviewer: Mark for all mentioned without reading out loud

- [ ] 1.Child used toilet/latrine
- [ ] 2.Put/rinsed into the toilet or latrine
- [ ] 3.Put/rinsed into drain or ditch
- [ ] 4.Disposed outside premises
- [ ] 5. Thrown into garbage
- [ ] 6. Buried
- [ ] 7. Disposed of in the yard
- [ ] 8.Others (Specify)…………

5.Do you think the current fecal sludge management trend cause harm? If yes, what are those health hazards? Interviewer: Mark for all mentioned without reading out loud

- [ ] 1.Diarrhea
- [ ] 2.Cholera
- [ ] 3.Typhoid
- [ ] 4.Intestinal worms
- [ ] 5.Other (specify)……………………………

6.Have children under age five in the household had diarrhea or typhoid in this year?

- [ ] 1.Yes
- [ ] 2.No

Part 5: Level of satisfaction regarding sanitation facilities and performance of service providers

1.Please rate your satisfaction level for the following aspects of the sanitation facilities of your household?

	1.Very satisfied	2.Satisfied	3.Dissatisfied
1.1 Quality of construction			
1.2 Ease of access			
1.3 Privacy			
1.4 Cleanliness	.		
1.5 Distance to toilet			

2.Please rate your satisfaction level with emptying service provider in terms of:

	1.Very satisfied	2.Satisfied	3.Dissatisfied
2.1 Price			
2.2 Overall service quality			
2.3 Ease of obtaining service			

3.How much are you willing to add up to the current payment for emptying service to improve the level of service? ……..……. Birr

Appendix 2: Checklists for Key Informant Interview

KII 1. Checklists Water supply and sewerage authority

Organization Name: Water supply and sewerage service enterprise

Telephone: ……………….…Fax………... E-mail……………...Web-site………………….

Organization Type: Governmental

Name of the informant: ………………………………………………………………

1. Explain the overall institutional structure, obligation, and roles of your department.
2. What are the proposed ongoing projects, future strategic plans, regulations, and its implementation & monitoring mechanisms of fecal sludge management in Kombolcha town?
3. Does your department request different stakeholders of fecal sludge management to participate both in the planning and enactment process of fecal sludge management? If yes, please describe those companies and their major activity.
4. Mention the types and the total number of equipment that your department used for the collection, transportation, and disposal of fecal sludge in the town?
5. Do you think that there is the insufficiency of equipment and manpower in your organization? If there is, what do you think the cause behind this and what are your future improvement plans?
6. Is there a treatment element for the sludge disposal and reuse occasion of the sludge? If there is, please describe the number of treatment units, their treatment capacity, percentage treatment efficiency and major problems encountered in managing the treatment unit?
7. Is there a difference between the amounts of fecal sludge that regularly generated in the town and, the total quantity of fecal sludge that is collected and disposed of by your department? If there is, please discuss the major causes of a gap.
8. Have you organized any training or capacity building for your employees? if so, what were the topics and how appropriate was it?
9. What is the department budget for sanitation, fecal sludge management? And what is the average monthly income and expenditures to manage the services?

10. What laws and regulations exist for fecal sludge management concerns? And how are those laws and regulations enforced? If there are no regulations, what solutions exist?
11. What is the main source of drinking water for the communities of town? Please mention
    - ❖ Number of boreholes and their respective yield
    - ❖ Percapita water demand and supply
    - ❖ Percentage of water supply coverage
    - ❖ Percentage of house connection shared and public tap users
12. What do you think should be done to improve the current situation of fecal sludge management practices in the town?
13. If you have any useful documents or previous researches that gives more information regarding sanitation (fecal sludge management), please provide the data.

KII 2: <u>Semi-structured interview guide for Emptying Service Providers</u>

Organization Name: <u>Water supply and sewerage service/ private emptying service providers</u>

Organization type: <u>Governmental/private</u>

The number of informants: Governmental……………private……………

Position: **<u>Vacuum truck driver (private and/or governmental)</u>**

1. How long are your daily working hours (start and closing times)? And working days per month?

2.What is the number of days in the service of trucks per year (days/year)? Are there periods (days, weeks, months when evacuating activity is greater / lesser? When? Why?

3. What is the daily frequency of your vacuum truck to the disposal site?
4. How much do you think is the average distance of disposal sites from the center of the town?
5. How much is the capacity of your vehicle in liters or m^3?
6. What average volume of pits and septic tanks do you experience in evacuating from different categories (institutions, condominiums, restaurants/hotels, industries, and single households)?
7. What type of on-site sanitation technologies do you empty (septic tanks, pits, etc.) and do you get entree to all the houses? If not, what do you do?

8. Do you think most of the households are willing to pay for evacuating their pits/tanks? If no, what motivates communities or households to demand and use proper latrine emptying services?
9. What is the will of the nearby farmers to use the sludge as a soil conditioning or fertilizer? Are they willing to pay for the sludge? If yes, how much Birr?
10. Have you ever attended any training? If yes, please describe the training and who is in charge of delivering training?
11. What personal protective equipment do you use during operation (emptying and transportation of fecal sludge)?
12. How much do you know laws and regulations associated with emptying and transport of fecal sludge? Who enforces the laws and regulations? Do no penalties exist? If so, please describe them.
13. What are the health problems you get related to your work and how often do you go to the health center/clinic?
14. How often did you service your vehicles last year? And what was the average time to access vehicle maintenance (in hours)?
15. What is the average time taken to get desludging service from the time of placing a request for service?

KII 3: <u>Checklists for Kombolcha town Municipal Authority</u>

1. What are the overall institutional structures, roles, and responsibilities of the municipality so as to deliver well-organized sanitation arrangements to Kombolcha town?
2. What are the ongoing and future strategic plans and sanitation projects that have been proposed for efficient fecal sludge management? If any, what are the proposed results?
   - ❖ Number of new and rehabilitate able public toilets/communal toilets
   - ❖ Rehabilitation or capacity increment in the fecal sludge treatment plant
   - ❖ Number of new vacuum trucks and their capacity
3. How many numbers of public toilets and communal toilet seats are available in Kombolcha town? How is fecal sludge managed? What is the approximate number of the population depending on such public and/or communal toilets?

4. Does the municipality have a link with different organizations (NGOs) who participate both in the planning and enactment process of fecal sludge management? If yes, please describe those companies and their major activity.
5. Did the municipality set laws and regulations in relation to fecal sludge management arrangements? If yes, how are laws and regulations enforced? If no regulations, is there any prospect of publishing municipal decrees?
6. Does open defecation go to be decreased or increase in Kombolcha town? If it increases or decreases, can you suggest the reason? Do you have any evidence to what extent it decreases or increases? What areas are being affected?
7. What is the total municipal budget for sanitation (solid waste and fecal sludge management)? And describe the average monthly income and expenditures to manage the services?
8. Are there any private sludge emptying service providers in the town? If any, please list them with the respective number of vacuumed trucks and capacity.
9. What are the identified slum areas or ketenas in the town? Are there subsidizations (financial supports) accessible, if a household needs support to improve their sanitation facilities (to repair, build or empty a latrine)? If there is, please specify.
10. Mention the types and the total number of equipment of the municipality that used for collection, transportation, and disposal of fecal sludge and solid waste in the town?
11. Are you aware of manual emptiers and illegal sludge dumping? If yes, how is sludge transported to the disposal site manually? What did the municipality do to manual emptiers?
12. Do you think households are willing to pay for evacuating their pits/tanks? If no, what motivates communities or households to demand and use proper latrine emptying services?
13. What are the main challenges in the management of the fecal sludge? Also related to population growth, urban expansion, land uses, and geographical features (slope, rivers, …).
14. What types of capacity building services have been conducted in the past? Do you have any capacity building plans for fecal sludge management?

15. If you have any useful documents or previous researches that gives more information regarding sanitation (fecal sludge management), please provide the data.

KII 4: <u>Checklists for Kombolcha town Health Department</u>

1. What are the organizational structures, roles, and accountabilities of the department related to sanitation and hygiene?
2. How does the department ensure that households toilets are dislodged when they become full so that there will not be any ecological and community health hazards?
3. Has there been a diarrheal epidemic affecting numbers of persons in the past year especially children under age five? If yes, please provide the statistics.
4. Do you have any strategies to implement so that sanitation services delivery will be sustainable and independent of the donor's subsidy?
5. What are your general recommendations to improve the delivery of sanitation services?
6. What are the identified slum areas or ketenas in the town? What support given to them to improve their poor sanitation arrangements?
7. Do you have legal recorded documents or statistics relating to children under five age having health hazards due to lack of proper fecal sludge management? If yes, please provide the data
8. Are you aware of any current improvements made to pit/septic tank evacuating services in the town? If yes, please mention the improvements made?
9. If you have any useful documents or previous researches that gives more information regarding sanitation (fecal sludge management), please provide the data.

KII 5: <u>Checklists for sanitation and beautification department</u>

1. What are the institutional arrangements, responsibilities, and roles of your department related to fecal sludge, wastewater, and solid waste management?
2. How do justify the current fecal sludge management practice at public/communal, household and institutional level?
3. How is the department taking care of hygiene practices, groundwater pollution from leachates, Instances of offensive Odour and uncontrolled dumping of fecal sludge?
4. What are other responsible governmental and non-governmental bodies involved in sanitation issues in Kombolcha town and how they are involved?

5. How does your department involve in managing fecal sludge at all stages of the sanitation service chain containment, emptying, transport, treatment and disposal/reuse?
6. Do you have any evidence of environmental pollution and disease transmission incidents because of uncontrolled fecal sludge management practice? If yes, give the data and suggest what should be done to improve the current situation?
7. What do you think inhabitants of Kombolcha town have clear and adequate awareness about proper fecal sludge management practices at the household level?
8. Are you aware of where do the private workers dispose of the fecal sludge and who is in charge of the management of those disposal sites?
9. Does open defecation go to be decreased or increase in Kombolcha town? If it increases or decreases, can you suggest the reason? Do you have any evidence to what extent it decreases or increases? What areas are being affected?
10. Do you think most households are willing to pay for evacuating their pits/tanks? If no, what motivates communities or households to demand and use proper latrine emptying services?

KII 6: <u>Checklists for Kombolcha town health extension workers</u>

1. What are your responsibilities and what roles do you play as a stakeholder in managing fecal sludge and solid waste in the town?
2. Does your organization give training, incentives, promotions and salary increment to you? If yes, how do you evaluate the level of training, promotions, incentives, and wages increment opportunities offered to you and your workmates?
3. Do you mention the sanitation habits of the poor communities in Kombolcha town?
4. Do you have statistics related to toilet facilities at the household level in the town? If yes, please provide the information.
5. Have you ever organized any training for the community related to sanitation or fecal sludge management practices? If yes, how was the knowledge and perception of the community regarding health hazards due to lack of proper fecal sludge management?
6. Do you have any data in the percentage of open defecation practices and disease transmission incidents because of uncontrolled fecal sludge management practice? If yes, what should be done to improve the situation?

7. Do you have any documents relating to children under five age having diarrhea, cholera, or Typhoid in the last one year? If yes, please provide the data
8. Do you think most households are willing to pay for evacuating their pits/tanks? If no, what motivates communities or households to demand and use proper latrine emptying services?
9. What previous provisions have worked well in the town so as to improve fecal sludge management practices? Who was in charge of these actions and how were local inhabitants involved?

KII 7: <u>Checklists for fecal sludge treatment plant supervisor</u>

1. What are your roles and responsibilities at the fecal sludge treatment plant?
2. Please describe following how the treatment plant working,
    - ❖ Maximum capacity of plants/plant
    - ❖ The average daily volume of fecal sludge discharged at the plant
    - ❖ Average daily Volumes treated/ proportion of delivered sludge gets treated
    - ❖ treatment efficiency
    - ❖ Discharge standards and quality tasting activities
3. Is there any further treatment (re-use) occasion of the fecal sludge to make additional income? If yes, how much is reused and for what purposes? If no, what are the opportunities to reuse the fecal sludge to generate income?
4. Do you have a recorded daily average number of trucks and their respective capacity arriving at the plant? Does it cope with the present demand and how long for future demand?
5. Do you mention monitoring, operations and maintenance arrangements (technical, administrative, and institutional frameworks) to ensure the long-term functionality of the plant?
6. Do you get paid from private fecal sludge emptying service providers to discharge fecal sludge? If yes, how much does it cost per trip or m^3? Who manages income and expenditure?
7. Have you ever attended any training before? If yes, what were the topics and how useful was it? In what capacity building would you be interested in getting training?

8. Do you receive any external support to manage the plant? If yes, from which organizations? What kind of support do they give?
9. Do you have manual/procedures to be followed during the operation and maintenance of the plant?
10. What major problems do you face in managing the treatment plant related to the operation, maintenance, funding, and monitoring?
11. If you have any useful documents (detail design paper) and manual that gives more information regarding fecal sludge treatment plant, please provide the data.

KII 8: <u>Checklists for fecal sludge treatment plant attendants/security persons</u>

1. How long is a daily working hour (start and closing times) at the treatment plant?
2. Are there any regular monitoring, operation and maintenance schedules? If yes, who is in charge of such regular monitoring, operation and maintenance activities of the treatment plant?
3. Do vacuum truck operators evacuating the fecal sludge close to the plant or somewhere to not pay for discharging fees? If yes, is there any means of punishment for illegal dumping?
4. Do you have daily recorded an average number of trucks their capacity? Please list different emptying service providers and their number of trucks and types.
5. Are there any fecal sludge reuse instances with or without treatment by the nearby farmers? If yes, for what purposes and how much does it cost?
6. Do you get paid from private fecal sludge emptying service providers to discharge fecal sludge? If yes, how much does it cost per trip or m^3?
7. Please mention the main problems that currently seen at the treatment plant.

KII 9: <u>Checklists for a septic tank or pit latrine installers/Masons</u>

1. Do you have any legal license to construct/install a septic tank or pit latrines? If yes, who in charge of giving licenses and monitoring such activities?
2. How many and what types of on-site sanitation technologies do you construct on average (per month or per year)? And who are your clients/customers?
3. How much do you know laws and regulations related to building septic tanks and pits? Who enforces those laws and regulations? Do no penalties exist? If so, describe them

4. What are the sizes of the tanks or latrines you commonly construct (length, width, and depth)?
5. How do you mostly construct on-site sewage collection systems related to fully lined, partially lined or totally unlined tanks or pits? With what material do you construct (with reinforced concrete, masonry or other)?
6. Do you construct septic tanks with having a compartment and proper outlet? If yes, with how many compartments you usually construct? What is your idea of where the outlet connected to?
7. What main problems do you face during the installation of a septic tank or latrines related to soil property, groundwater table occurrences, and land availability? In which locations or kebeles?
8. How much Birr do you get paid from households for constructing their pits or septic tanks?

KII 10: <u>Checklists for public toilet attendants</u>

Location…………………………

1. How long are your daily working hours (start and closing times)?
2. Do you have a recorded average number of customers per day?
3. Do the customers have to pay to use the toilet? If yes, how much?
4. What anal cleansing materials are given to the users (water, soft, paper, etc.)?
5. How do you dispose of the anal cleansing materials?
6. Do you have handwashing facilities? If yes, do users exercise handwashing?
7. How often do you clean the toilet and with what cleaning materials?
8. What is the average rate (frequency) of desludging the toilet?
9. Do you pay for desludging the toilet? If yes, how much do you pay for desludging the toilet per trip? If no, who is in charge of desludging without payment?
10. What is the average waiting time (in minutes) to access the public toilet seat?
11. Who is in charge of paying your salary, monitoring, and supervision of this public toilet?
12. What major problems do you face in managing the toilet related to maintenance, and monitoring?

Appendix 3: Tables

Table 12: Kombolcha town climatic data

Months of a year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average high Temp. in (°C)	23.9	24.6	25.4	26.6	28.2	29.9	27.5	26.1	25.4	24.6	24	23.4	25.8
Daily mean Temp. in (°C)	17.2	18.4	19.7	20.4	21.7	23.3	21.6	20.6	19.9	18.4	17.1	16.6	19.6
Average low Temp. in (°C)	9.4	10.5	11.8	12.6	12.6	13.7	13.3	12.9	12.4	9.8	8.1	8.4	11.3
Average rainfall (mm)	29	39	80	89	64	32	253	246	122	32	20	19	1,027
Average rainy days (≥ 1.0 mm)	3	5	9	9	8	4	20	21	14	4	2	2	101
Average relative humidity (%)	58	56	62	58	46	35	56	64	62	61	56	57	56

Source: (Kombolcha Meteorology station, 2019)

Table 13: The frequency of vacuumed trucks unloads/dislodge at the plant

Months of the year	**Years**								
	2017			**2018**			**2019**		
	Municipal truck	Private trucks	total	Municipal truck	Private trucks	total	Municipal truck	Private trucks	total
September	65pri/32 org	84	181	19/30	50	99	34/30	284	348
October	60/37	3	100	67/31	215	313	Maintenance	335	356
November	63/35	103	303	51/32	77	160	Maintenance	537	537
December	94/68	104	266	33/39	50	122	77/33	153	263
January	34/35	53	122	18/10	4	32	47/40	4	91
February	55/5		60	44/63	176	283	26/21	209	256
March	Maintenance	262	262	66/10	158	234	57/21	4	82
April	Maintenance		0	57/11	269	337	Maintenance	104	104
May	125/23	57	205	22/31	89	143	89/7	247	343
June	94/19		113	43/8	133	184	41/20	115	174

July	87/29		116	52/33	198	283	53/17	226	296
August	79/39	70	193	58/86	215	359	33/11	210	254
Sub total	**1,083 trips**	**736**		**912 trips**	**1,634**		**658 trips**	**2,428**	
Total	**1,819 trips**			**2,546 trips**			**3,086 trips**		
Pri = Private and Org. = Organazation									

Table 14: Toilet facilities in Kombolcha town urban kebeles

Urban Kebeles	All toilet technologies	Improved toilet facilities	Unimproved toilet facilities	Improved facility coverage in (%)
01	1996	1691	305	84.7
02	3562	3099	465	87
03	2103	1852	251	88
04	4008	3700	308	92.3
05	4994	4994	0	100
12	2039	1705	334	81.4
Total	**18,702**	**17,041**	**1663**	**91.11**

Source: (Kombolcha town health office,2019)

Note: Unimproved toilet facilities are traditional latrines that had no roof (plastic roof), temporary & non-permanent wall and wood slab or no slab at all (open pit latrine).

Table 15: Calculation of risk using groundwater assessment helper tool

		Hilly area (Cluster 9)		**Lowland areas (Cluster 3,5, &7)**	
Q1: Vulnerability of Aquifer					
A	What is the rock type in the unsaturated zone	Fine sand, silt, and clay	**Significant risk**	Fine sand, silt, and clay	**Significant risk**
B	What is the depth to the groundwater table	<5m		<5m	
Q2: Lateral Separation					
A	What is the percentage of sanitation facilities that are located <10m from the groundwater sources?	Less than 25%	**Significant risk**	Less than 25%	**Low risk**

B	What is the percentage of sanitation facilities, if any that are located uphill of the groundwater source?	Greater than 25%		Less than 25%	
Q3: Water Supply					
	What is the percentage of drinking water produced from groundwater sources?	Greater than 25%		Between 1% and 25%	
Q4: Water Production					
	What is water production technology used?	Unprotected spring		protected boreholes dug wells or springs	
OVERALL RISK			**Significant risk**		***Low risk***

Table 16: Final SFD matrix containment estimations and Reference Variables

Own variable	Containment technologies	Estimations	SFD Reference Variables
F2 (e)	Fully lined tank, no outlet or overflow	**1.5%**	T1A3C10
F2 (e)	lined tank with impermeable walls and open bottom, no outlet or overflow	**10%**	T1A4C10
F10 (e)	Lined/partially lined tank discharged to open drain/water body	**9.5%**	T1A4C6
F2 (e)	Lined pit/tank with semi-permeable walls and open bottom, no outlet or overflow	**46%**	T1A5C10
F2 (e)	Unlined pit with no outlet or overflow	**11%**	T1A6C10
F2 (n)	Pit latrines abandoned when full and covered with soil, no outlet or overflow	**8%**	T1B7C10
F10 (n)	Pit latrines abandoned when full and covered with soil, no outlet or overflow in significant GW risk areas	**3.2%**	T2B7C10
F10 (n)	Containment failed, damaged, collapsed or flooded - no overflow	**3.8%**	T1B10C10
OD	Open defecation	**7%**	T1B11 C7 TO C9

Appendix 4: Figures

Figure 4.1a: Traditional latrine

Figure 4.2b: Simple pit latrine

Figure 4.2 Ventilated Improved Pit (VIP) latrines

Figure 4.3a: Septic tank at rest

Figure 4.3b: Septic tank during emptying

Figure 4.4a: Municipal vacuumed truck discharging fecal sludge at FSTP

Figure 4.4b: Some of the private vacuumed truck discharging fecal sludge at FSTP

Figure 4.4c: Long hose from a municipal vacuumed truck during fecal sludge emptying

Figure 4.5a: Drying bed in use

Figure 4.5b: Drying beds at rest

Figure 4.6: Storage lagoons

Figure 4.7: Maturation pond

Figure 4.8: Cake/dried sludge removal from drying beds (photo by kedir 2009)

Figure 4.9a: Animalsi inside drying beds and urban settlements around the FSTP

Figure 4.10a: Drying bed cells with fractured common walls

Figure 4.11a: Condominium septic tank overflow and discharged to open drain

Figure 4.11b: Faecal sludge leakage from communal toilets

Figure 4.11c: Illegal FS discharge

Figure 4.11D: FS discharge into collapsed containment

Figure 12a: Pit latrine with wood slab   Figure 12b: Children faeces exposed to contact

Figure 12c: Collapsed pit user interface

Figure 12d: Dumped solid waste in water bodies   Figure 12e: Tank waiting for emptying

Figure 4. 13: Different protected private groundwater sources in Kombolcha town

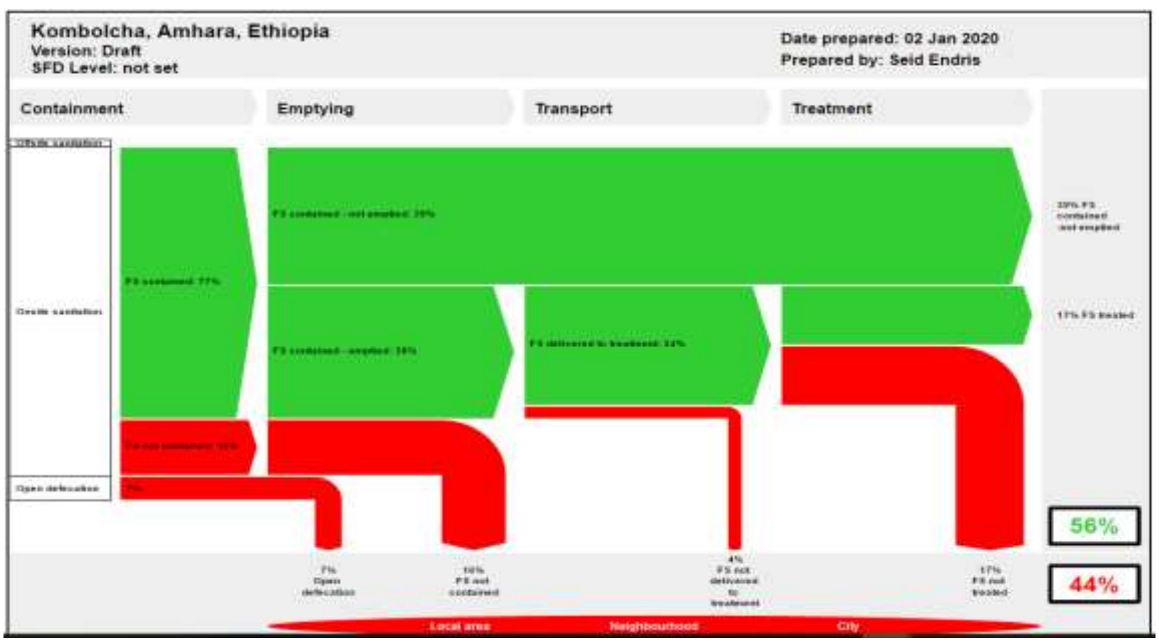

Figure 4.14 Citywide Sheet flow diagram tool output